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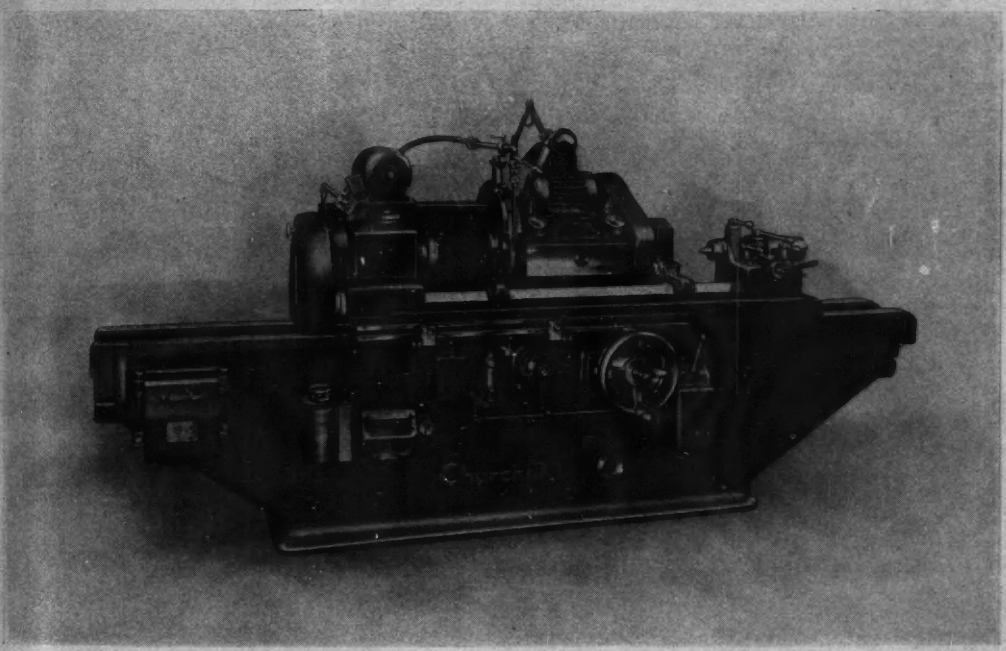

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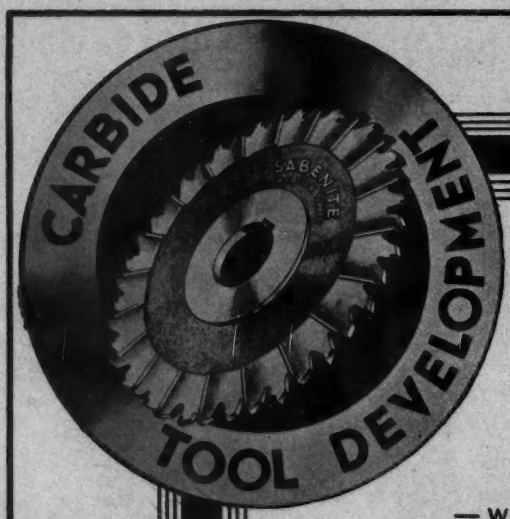

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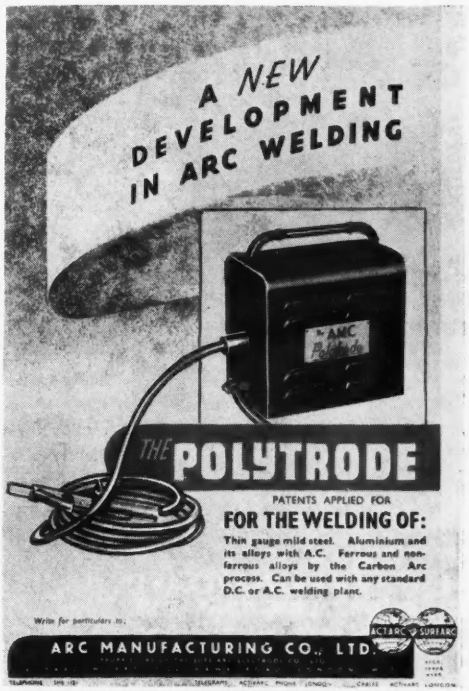
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KNOWLEDGE KNOWS NO FRONTIERS.

THE purpose of THE ENGINEERS' DIGEST *is to promote collaboration between scientists and engineers all over the world by disseminating international technical knowledge. No emphasis need be laid on the importance of this task, as it is generally agreed that all great and fundamental technological achievements of the past have resulted from such international co-operation. The overwhelming volume of technical literature published daily in all parts of the globe, on various subjects and in many languages, makes this work extremely complex. The labour and expenditure in connection with securing, selecting, and translating into English the foreign technical papers would, therefore, be not only uneconomical and impossible for the individual engineer and research worker, but could scarcely be afforded by even the largest industrial concerns.*

During the war this task was complicated by official restrictions on imports from enemy and enemy occupied countries and, by the reluctance of these countries to export papers containing valuable technical information. Communication problems have added to these difficulties whilst the availability of technical details on European research and engineering developments became of increasing importance to the Allied nations.

A list of the 800 *technical papers and articles, abstracted and translated from current European journals during the war, has now been published in a carefully prepared* 32*-page Index of the first six volumes of* THE ENGINEERS' DIGEST. *It is not only a source of reference of lasting value, but it shows that, in our strong desire to contribute to the magnificent war effort of our engineering industries, we were able to master many of the difficulties.*

Since the cessation of hostilities it is again possible to communicate freely with foreign countries, although certain restrictions still prevail in some European lands. But most of the foreign technical periodicals, temporarily suspended during the war, have recommenced publication, engineering activities are increasing in the industry as well as in research laboratories and professional institutions. At the International Technical Congress to be held in Paris in September, Great Britain and the United States will be duly represented. This is a step in the right direction.

One of the countries, whose technical progress has been periodically reviewed from the very first issue of THE ENGINEERS' DIGEST, *is Russia, known to English speaking engineers rather for the gallant resistance of her people to German aggression than for the fine achievements of her scientists and engineers. British and American scientists and engineers who were invited to the celebrations of the 220th anniversary of the foundation of the Russian Academy of Sciences in Moscow in June,* 1945, *were much impressed by the excellent equipment in their research laboratories and by the generous facilities afforded to engineers and scientific workers. They have found that Russian scientists and engineers were equally keen to travel abroad; to see laboratories and engineering works in foreign countries, and to discuss their problems with foreign colleagues. It is to be hoped that they will be given greater freedom to do so than has been the case in the past. The outstanding importance of Russian developments is strikingly illustrated by the ambitious aims laid down in the "Law on the Five-Year Plan,* 1946-1950," *and adopted by the Supreme Soviet of the U.S.S.R. on March* 18, 1946. *Quoting this official document, the aim of the Soviet Union is the "overtaking and outstripping the principal capitalist countries economically, i.e., with respect to the volume of industrial output per head of the population." This Five-Year Plan provides, e.g., for an increase in machine tools to* 1,300,000 *by* 1950, *or* 30 *per cent more than were used in the U.S.A. in* 1940. *A most impressive expansion in all other engineering fields is also provided by the Plan.*

Industrial activity on such a large scale by a nation of 180,000,000 *implies research and development work of the utmost significance and interest. We shall endeavour to review regularly such developments as reflected in the excellent Russian technical press and by way of direct contact with the responsible scientists and engineers. The present issue is devoted, to a large extent, to articles on industrial life and engineering developments in Russia. Some of the articles have been abstracted from recent Russian engineering periodicals. Others are based on the accounts of responsible engineers who have recently visited the Soviet Union. We have applied for permission for a member of our editorial staff to visit Russia and as soon as this is granted, a visit will be made. In the meantime we have been promised all possible assistance in securing current Russian technical literature, and it is hoped that our editorial material on Russian developments will not only be of practical interest from the strictly engineering point of view, but that it will also contribute to the gradual development of friendly personal relations between English-speaking engineers and their Russian counterparts, and thus be a step towards establishing the fact, that the quest for knowledge knows no frontiers.*

THE EDITOR.

THE ELECTRICITY SUPPLY INDUSTRY IN SOVIET RUSSIA.

By L. Kopec and B. Perlin. (From *Electrotechnicky Obzor*, Vol. 34, No. 15-16, November, 1945, pp. 228-230.)

GENERAL

The first steps to ensure an organic development of the electricity supply in accordance with the desire to transform agricultural Russia into an agro-industrial State were taken in 1920 as part of the first 5 -year plan. From then onward great effort was devoted to the development of electricity supply and as a result of this, Russia whose electricity production in 1918 had been below that of Switzerland, became the third largest electricity producer in the world after the U.S.A. and Germany (about 50 milliard kWh production in 1940 compared with considerably less than 2 milliard kWh in 1918). The present electricity consumption in Moscow is about 800 kWh per head per annum, i.e., about twice the corresponding figure for Prague.

The success of the electrification in the Soviet Union is attributed to five basic principles followed, which form a part of the state planning and which are characteristic for the conditions in that country.

1. Electricity producer and consumer are not considered as two distinct groups, but the electricity production and consumption form one economic unit for which planning can be carried out better and more economically and which can be controlled from one common point. For instance, the planning of the Dneprostroj power station (558 MW) was carried out together with the planning of the industrial works which were to consume the output of that station. In this way, the highest efficiency and best utilization can be obtained of the large power stations.

2. Emphasis is laid on the utilization of local low grade fuels, and power stations were built direct on the deposits of such fuels. Thus high quality coal was replaced, as a fuel, by peat, anthracite and coal dust; low grade coal from deposits near Moscow, Cheliabinsk and elsewhere; and other low grade fuels. At Gorki (Nijni Novgorod) for instance the largest peat firing station in the world (204 MW) was built, firing peat of 3,500 kcal/kg. and of a moisture content of 25 per cent. At present, about 80 per cent of all the power stations fire exclusively local fuel.

3. The third principle consists in combining the electricity production with steam supply for industrial and other purposes, for the purpose of obtaining higher thermal efficiency. At present, power stations accounting for about 25 per cent of the total capacity of the country supply electricity as well as steam. In this connexion, a number of important technical and economic problems had to be solved and Russia now occupies the first place in this branch of power supply.

4. The fourth basic principle is the highest possible utilization of water power. Before 1914, there existed practically no water power stations in Russia, although the potential water power was estimated to be 280,000 MW. Since 1920, a large number of water power stations were built, the largest and best known of which are Volkhov, Svir and Dnieper.

5. The fifth principle is the creation of a unified high tension transmission system for the whole country; when completed, this will interconnect all the principal industrial areas. Some of the long distance transmission lines built so far (e.g., the 1,000 km line from Solikans to Magnitogorsk) proved invaluable when, during the war, industries had to be evacuated from the western to more easterly zones.

One of the deciding factors during the war was the effectiveness of the electricity supply system, which in turn was to a considerable extent due to the methods, based on scientific studies, used to speed up the construction of power stations. For instance, the power station at Cheliabinsk was built in nine months instead of the usual two years required for similar stations, and a 100 at. high pressure Ramzin boiler was erected in only three months. The latter type of boiler was developed in a specially built power station which contains boilers of the Loeffler, Benson and Ramzin types and which operates on the grid in the normal way.

II. THE ORGANIZATION OF ELECTRICITY SUPPLY

The Soviet Government attaches no particular importance as to whether the individual power stations are under the control of the State, of municipal corporations or of industrial works. The main concern of the experts in charge is reliability and economy; electricity must be as cheap and the supply as secure as possible.

The electricity supply undertakings are divided into four groups. The most important group are the large district power stations which account for about three-quarters of the total installed capacity of the country; they come under the jurisdiction of the Ministry of Electricity Supply; there are four regional grid systems comprising the most important industrial and mining areas: the southern system (Donetz basin and Dnieper area including Rostov, Taganrog and Mariupol), the central system (Moscow, Ivanov and Gorky districts), the eastern system (Ural with Magnitogorsk) and the northern system (Leningrad area). Each of these four grid systems is controlled by a load dispatcher.

The other three groups which account for together 25 per cent of the total installed capacity of the country comprise respectively the municipal stations (under the Ministry for Municipal Affairs), rural stations (under the Ministry for Agriculture) and finally the industrial power stations. These three groups, and especially the municipal and rural stations, are all of small capacity and are of only local importance.

Although the four groups are under the supervision of four different ministries, the planning for all of them is carried out centrally by a planning commission. Thus the interests of the State as a whole can be put before purely local interests. There is, for instance, no objection in principle to the erection of a local power station even if a high tension line passes nearby and if tapping would be easy and inexpensive. Each case is judged on its merits and permission to build such a station is granted if, e.g., local low grade fuel or cheap water power is to be utilized, or if other circumstances favour such a decision.

III. THE MANAGEMENT OF THE INDIVIDUAL SUPPLY UNDERTAKINGS.

Each of the four regional grid systems has a managing office under whose jurisdiction come all the regional supply undertakings in the respective areas. Each individual supply undertaking has a manager who is nominated by the Ministry for Electricity Supply. The other senior employees of the undertaking are nominated by the regional managing office, while the remaining staff is chosen by the manager himself. The whole responsibility for the technical and economic management of the undertaking rests with the manager, who therefore enjoys considerable powers which he shares with no one else. The duty of the works council is to assist the manager in the management of the undertaking and to co-operate on social and cultural problems. In the works rigid discipline is ensured by the combined efforts of the manager, the works council and the staff. In cases of breach of discipline, the manager has the power to dismiss any member of the staff without being responsible to anyone. If, however, the works council disagrees with the severity of the manager's decision,

it can appeal to higher authority. It is said that such a case has not yet occurred as the works council are in constant consultation with the manager and punish an employee, where this is warranted, as a means of educating the staff. The employees feel themselves co-owners of the undertaking and therefore have an honest attitude towards their duties.

Each supply undertaking is given a definite task by the regional managing office which must be fulfilled under all circumstances ; for this, the responsibility rests with the manager. In general, the task is defined by: 1. a definite load curve ; 2. a maximum permissible cost per unit ; 3. efficiency ruling, as for instance the maximum fuel consumption per kWh, the wages per kWh and the allowed house consumption. These tasks are not rigidly fixed but are continuously being checked and, if necessary, revised. If a better performance is achieved than that prescribed, the profit is shared between the staff of the undertaking, including the manager, and the State. The profit of an undertaking consists of two parts : the first is the difference between the selling price and the maximum permissible cost of production as prescribed by the plan, while the second part is the difference between the latter and the lower cost of production actually achieved ; the staff participates only in the latter part of the profit. If, on the other hand, the task is not fulfilled and if it is proved that this is due to bad management, the manager is replaced ; if there are other causes the manager is given a time limit for their removal.

The wages of the employees of the undertaking are determined by their qualifications and the amount of work done by the individual worker ; as a result of this, wages differ even within one category of employees. However, a certain minimum of work is required of any employee. For heavy work, higher wages are paid and bigger food rations and longer holidays provided ; in underground mines the working hours are reduced from eight to six hours per day.

The inflow of workers into individual industries is controlled indirectly and " entrance examinations " are introduced in branches where the supply of labour is larger than the demand. This enables the industry to turn away the surplus labour while at the same time it gives an opportunity to those particularly fitted to join the industry.

RUSSIA

HYDRODYNAMIC THEORY OF HEAT EXCHANGE AND DIFFUSION IN TURBULENT GAS FLOW IN PIPES.

By Z. F. CHUKANOV. (From *Reports (Doklady) of the Academy of Sciences of the U.S.S.R.*, Vol. 43, 1944, No. 7, pp. 277-282, 1 illustration).

ALTHOUGH it has made considerable progress, the hydrodynamic theory of heat exchange is still far from being perfect. Even in the case of heat exchange from a gas to a solid wall, with a Prandtl number of $Pr \simeq 1$, experimental data deviate considerably from theoretical findings, particularly for large values of the Reynolds number. This fact is emphasized by the accompanying graph (Fig. 1.) in which both theoretical and empirical values for the Nusselt number Nu as function of the Reynolds number Re are charted.

This divergence is usually ascribed to the assumption upon which the hydro-dynamic theory of heat exchange is based. It will be obvious that no fruitful development of the hydrodynamic theory or its extension to the heat exchange between liquids and surfaces for $Pr \neq 1$ is possible unless satisfactory agreement between experimental findings and theory has at least been established for the simplest case, i.e. heat exchange in the case of gas flow. The way towards a solution of this problem seems to lie in the investigation of the mechanism of interaction between the turbulent flow and the heating surface. On the basis of this analysis the author has attempted to establish a concept of the mechanism of interaction between the turbulent flow and the tube wall surface, and to derive from it equations of the hydrodynamic theory of heat exchange. That this attempt has not been without success may be seen from a comparison of the curve derived from the author's equation with the empirical curve given in the graph.

In the turbulent range rectilinear motion of the fluid does not exist, and the stationary laminar boundary sublayer is absent. Because of the damping of transverse pulsations, the conditions of motion near the tube wall are sharply different from those existing in the core of the flow. Near the wall the longitudinal pulsations are comparatively larger, and the conditions existing bear little resemblance to what is ordinarily described as a laminar flow condition ; nor are they similar to the normal turbulent condition of the core. A characteristic feature of this pseudo-laminar zone is that the transverse migration of matter and the transfer of heat are effected solely by way of diffusion and conduction, that is, in the molecular way. As this boundary is variable with time, the thickness of the pseudo-laminar boundary layer and the quantities characterizing the interface as well as the layer itself may only be assessed from the aspect of mean statistical values.

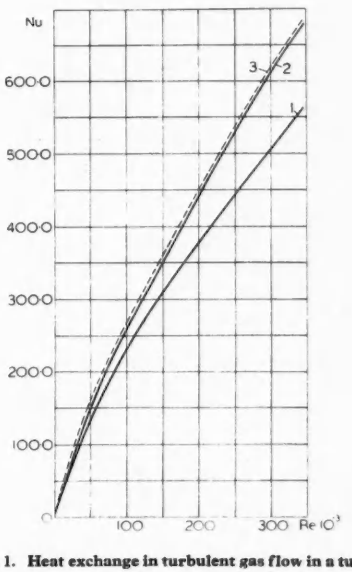

Fig. 1. Heat exchange in turbulent gas flow in a tube :

1. According to the theoretical equation of Reynolds, Tyler, Prandtl and Karman ($Nu = 0{\cdot}0396\ Re^{0{\cdot}75}$) ;

2. According to the empirical equation of Datus and Belter. ($Nu = 0{\cdot}0254\ Re^{0{\cdot}8}$) ;

3 According to the author's theoretical equation.

The intersection between the turbulent core and the boundary layer is determined by the mutual exchange of fluid due to velocity pulsations in a direction parallel to the wall. Obviously, this exchange is possible only because the interface, that is, the border of the laminar boundary layer—is not parallel to the wall of the pipe. Also, it is natural that the resistance to motion of the turbulent flow, as well as the quantities of heat and matter transferred to the boundary layer will be determined by the exchange of matter between the turbulent flow and the pseudo-laminar layer, and also by the conditions under which the corresponding process in the boundary layer takes place.

On the basis of this concept of the mechanism of turbulent flow, a quantitative relation may be established between flow resistance and heat exchange, and also between flow resistance and exchange of matter by diffusion in the presence of a concentration gradient towards the wall of the pipe.

If it is supposed that τ, i.e. the shear stress in the boundary layer, is constant and equal to the shear stress τ_0 at the wall, that is, the total resistance to the movement of the fluid is practically equal to the resistance to the movement of the turbulent core, then the loss of head will be determined by the loss of kinetic energy of that portion of the fluid in the turbulent core which penetrates into the pseudo-laminar layer. If Δ is the amount of fluid penetrating in unit time into the boundary layer over the length dx of the pipe, and dp is the loss in static head over the length dx, and r is the radius of the pipe, then the conditions of equilibrium will be given by

$$-\pi . r^2 . dp = \tau_0 . 2 . \pi . r . dx \quad .. \quad (1)$$

As $$dp = \frac{\Delta}{\pi . r^2 . \bar{w}} \frac{\bar{w}^2 - w_1^2}{2g} \quad .. \quad .. \quad (2)$$

where $\bar{w}$ is the mean velocity of the flow, it follows that

$$\tau_0 = \frac{\Delta}{2 . \pi . r . dx} \frac{\bar{w}^2 - w_1^2}{2 . \bar{w} . g} \quad .. \quad (3)$$

Since the transfer of heat from the turbulent core is effected by the same volume of the fluid, the amount of heat Q transferred to the pseudo-laminar layer is determined by the equation

$$Q = \Delta . c_p . (\bar{t} - t_1) \quad .. \quad .. \quad (4)$$

Or, in terms of unit area of wall surface :

$$q = \frac{\Delta . c_p (t - t_1)}{2 . \pi . r . dx} \quad .. \quad .. \quad (5)$$

By combining equations (3) and (5) the quantity of heat transferred from the turbulent core to the boundary layer is found as :

$$q = \frac{\tau_0 c_p . g (t - t_1)}{\bar{w} - w_1} \frac{2 . w}{\bar{w} + w_1} \quad .. \quad .. \quad (6)$$

By making

$$\Theta = \frac{\bar{t} - t_1}{\bar{t} - t_w} \quad .. \quad .. \quad (7)$$

equation (6) can be reduced to a form analogous to the equation $\frac{Nu}{Pe} = \frac{\zeta}{8}$, to wit :—

$$\frac{Nu}{Pe} = \frac{\zeta}{8} \frac{2\Theta}{1 - \left(\frac{w_1}{\bar{w}}\right)^2} \quad .. \quad (8)$$

where ζ is the coefficient of hydraulic resistance.

The factor Θ can be determined as follows : Considering the phenomena taking place in the pseudo-laminar layer, it is seen that the condition $\tau = \tau_0$ corresponds to a linear distribution of velocity in the boundary layer, that is,

$$\tau_0 = \mu . \frac{w_1}{\delta} \quad .. \quad .. \quad .. \quad (9)$$

where μ is the viscosity of the fluid and δ the mean statistical thickness of the boundary layer. The amount of heat transferred to the wall of the pipe is determined from equation (9) as

$$q = \frac{\lambda . \tau_0}{\mu w_1} (t_1 - t_w) \quad .. \quad .. \quad (10)$$

By combining equations (6) and (10) the value of Θ is found as

$$\Theta = \frac{1 - \left(\frac{w_1}{\bar{w}}\right)^2}{1 + \frac{w_1}{\bar{w}} \left(2Pr - \frac{w_1}{\bar{w}}\right)} \quad .. \quad (11)$$

By substituting in equation (8) the value of Θ from (11), it obtains

$$\frac{Nu}{Pe} = \frac{\zeta}{4} \frac{1}{1 + \frac{w_1}{\bar{w}} \left(2\,Pr - \frac{w_1}{\bar{w}}\right)} \quad .. \quad (12)$$

or in a form analogous to equation (6) :

$$q = \tau_0 \frac{c_p . g (t - t_w)}{\bar{w}} \frac{2}{1 + \frac{w_1}{\bar{w}} \left(2\,Pr - \frac{w_1}{\bar{w}}\right)} \quad (13)$$

The equation (12), which determines the heat exchange in the turbulent flow is valid for gases with $Pr \cong 1$. In equation (12) the factor ζ is determined solely by the loss in static head caused by the interaction between the turbulent core and the pseudo-laminar boundary layer. For $Re \leq 250{,}000$, ζ is accurately determined by the well known Blasius formula

$$\zeta = 0{\cdot}3164 . Re^{-1/4} \quad .. \quad .. \quad (14)$$

The determination of the characteristic ratio $\frac{w_1}{\bar{w}} = W$ is complicated by the fact that this ratio has so far defied direct experimental determination. There is no doubt that W is a function of the physical properties of the fluid and of the character of the flow, that is to say, in this case of the Reynolds number.

However, as this investigation is concerned with average values of W and δ, the value of W as applying to a gas and to conditions lying within the range to which Blasius' law is applicable, may be determined from Prandtl's equation

$$\frac{w_1}{\bar{w}} = C . Re^{-1/8} \quad .. \quad .. \quad (15)$$

where C_1 lies within 1·8—2·48.

On the basis of equations (15) and (14) the equation for the heat exchange for a gas can therefore be written :

$$Nu = \frac{a}{4} \frac{Re^{0.75}}{1 + 2C . Re^{-1/8} - C^2 Re^{-1/4}} \quad (16)$$

A curve based upon this equation and upon a value of $C_1 = 2{\cdot}0$ is given in the graph. It will be seen that this curve is in very satisfactory agreement with the empirical curve representing the evaluation of a vast amount of experimental data.

AUTOMATIC BOILER CONTROL SYSTEM.

By S. G. GERASIMOV. (From *Izvestya Vsesoyuznogo Teplotechnicheskogo Instituta*, No. 1, January, 1946, pp. 11-15; No. 2, February, 1946, pp. 22-28, 9 illustrations.)

A NOVEL electric system of automatic boiler control has been developed at the laboratory for automatic control of the All-Union Thermo-Technical Institute, Moscow. This system has been fitted to one boiler each at the Kashira and the Smidovich plants and also to one forced flow once-through boiler at the Krasnogorsk and the No. 9 Mozenergo plants. Furthermore, six installations have been fitted to six once-through boilers at the Krasnogorsk plant, the Chelyabinsk plant and the Stalinogorsk plant, and all are now coming into regular operation. The manufacture of the controls is carried out by the All-Union Heat Control Trust.

This boiler control system is of the fully electric type, and therefore has the advantage that no special sources of energy are required for its operation. Also the original control impulse may be very small, and several impulses can easily be superimposed. The employment of small electric currents makes it possible to use mercury contactors, thus dispensing with the use of relays and solenoids.

The control equipment for both natural circulation boilers and forced flow once-through boilers consists of five separate automatic controllers (Figs. 1 and 2). Three of these, namely, the pressure controller (1), the air controller (2), and the furnace draught controller (3) constitute the combustion control system; while the fourth and fifth controllers serve to control the feed-water (4) and the superheat respectively (5). The first three controllers are applicable to both boilers of the natural circulation type and of the forced flow type. The feed controller is of particular importance with regard to reliable and safe boiler operation both at base load and in the event of load and pressure fluctuations in the steam system and in the feed-water piping; the latter may cause inadmissible variations of the water level in the boiler drum.

Fig. 2 shows the automatic control system employed with forced flow once-through boilers. Here two temperature controllers are provided, (1) the steam temperature controller adjusting the temperature of the steam before the superheater, by adjusting the fuel supply, and (2) the water injection control which regulates the temperature of the steam delivered by the boiler. Steam temperature control is equally important at all load conditions, since for a variety of reasons the synchronism of fuel and water supply to the boiler tends to get lost, and this, if allowed to occur, would lead to inadmissible fluctuations in steam temperature. Outstanding factors in this respect are variations in the rate of fuel injection into the furnace and variations in the feed pump delivery. As regards the feed pump delivery, the experiences made at boiler No. 10 of the Krasnogorsk plant have shown the need for stabilizing the rate of delivery by the centrifugal boiler feed pump. Stabilization may be achieved either by employing pumps with a very steep characteristic, by which it is possible to dispense completely with any control gear, or by installing a differential pressure control if the pump has a falling characteristic.

The duty of the aforementioned pressure or load

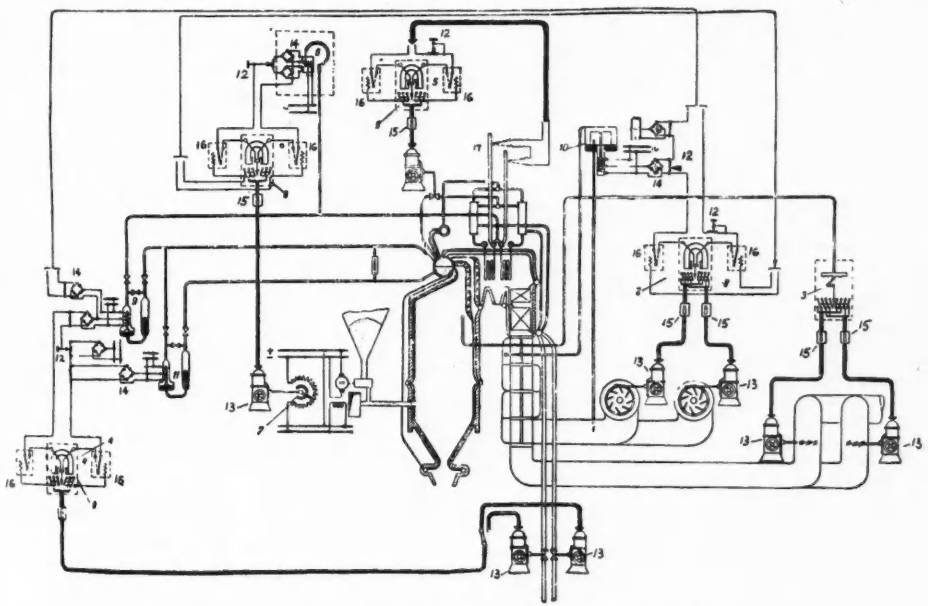

Fig. 1. **Diagram of automatic control for water tube boilers.**

1. Pressure controller.
2. Air controller.
3. Furnace draught controller.
4. Feed-water regulator.
5. Superheat controller.
6. Bourdon type pressure gauge.
7. Rheostat of motor driving p.f. feeder screw.
8. Galvanometer contacts.
9. Steam flow-meter.
10. Draught gauge.
11. Water level indicator.
12. Adjustable rheostat.
13. Servomotor.
14. Copper oxide rectifier.
15. Remote control switch.
16. Electro-thermal reset device.
17. Thermocouple.

controller is to maintain constant steam pressure at the boiler outlet. Its measuring element is a highly sensitive manometer which causes a control impulse to be passed to the servomotor operating the controller of the motor of the pulverized fuel feeder or to any other device controlling the rate of fuel feed into the furnace. In the case of a forced-flow once-through boiler the pressure controller simultaneously actuates the servomotor which controls the throttle valve in the feed-water line, thus ensuring approximate synchronism between the fuel feed and the feed-water flow.

The relatively high sluggishness of water tube boilers makes it necessary to provide a reset device which may be of the rigid or of the resilient type, the actual choice depending upon the existing conditions. Actually for both natural circulation boilers and forced flow once-through boilers the control gear referred to is furnished with an electro-thermal reset device.

The air controller serves to maintain a constant excess air ratio over the entire range of boiler load, that is to say, it controls the air/load ratio. In the case of forced flow once-through boilers it is more convenient to measure the boiler load in terms of feed-water flow, and the controller is therefore adapted to control the air/water ratio. (In natural circulation type boilers the control impulse is obtained from the steam flow-meter, while in once-through type boilers it is derived from the feedwater flow-meter). The resetting impulse is obtained from a bell-type differential draught gauge, which measures the draught loss across the air preheater. In boilers of the natural circulation type the air flow control gear is subjected to an additional control impulse derived from the pressure sensitive element.

The furnace draught control serves to maintain constant negative pressure in the upper part of the furnace. The actuating impulse is emitted by a draught gauge operating a servomotor which adjusts the various control gears. This controller is not equipped with a resetting device. Identical controllers are used for both natural circulation and once-through type boilers.

Latest types of feed-water control gear are built on the triple impulse system, the impulses being derived from the steam flow rate, the feed-water flow rate, and the water level in the boiler drum respectively. However, in the automatic control system under review only two main impulses are utilized, the one being derived from the steam flow rate and the other from the water level indicator. The control impulse is transmitted to a servomotor which adjusts the throttle valve in the feed-water line. A resetting device of the aforementioned electro-thermal type is incorporated.

The steam temperature control gear as fitted to natural circulation boilers is made to operate the de-superheating device, which may be of the water injection type or of the surface cooler type. The measuring element is represented by a thermocouple placed in the

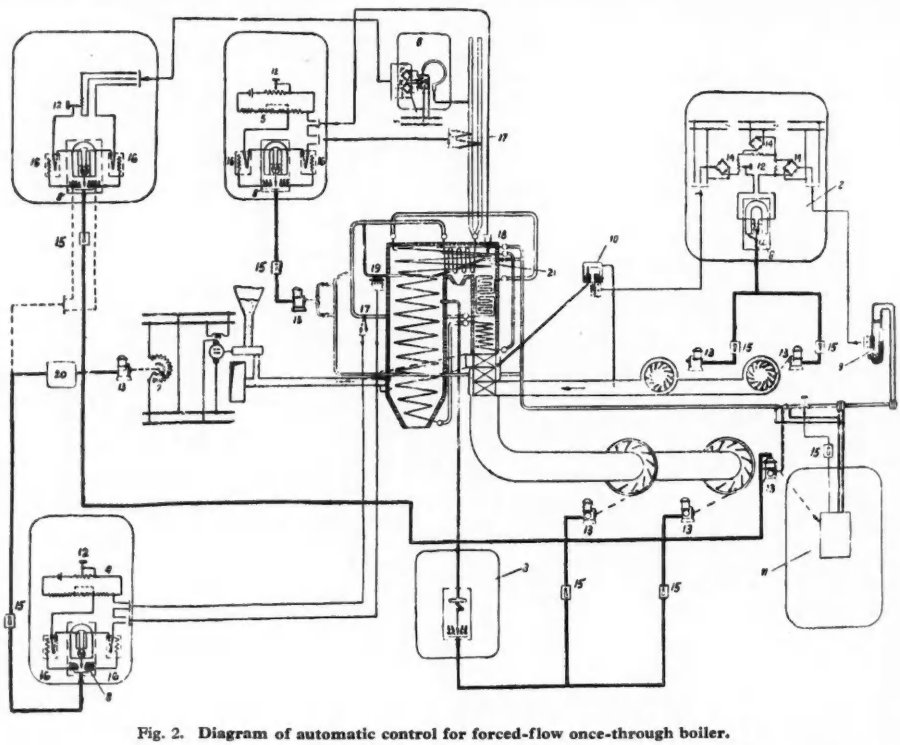

Fig. 2. **Diagram of automatic control for forced-flow once-through boiler.**

1. Pressure controller.
2. Air controller.
3. Furnace draught controller.
4. Feed-water regulator.
5. Superheat controller.
6. Bourdon type pressure gauge.
7. Rheostat of motor driving p.f. feeder screw.
8. Galvanometer contacts.
9. Steam flow-meter.
10. Draught gauge.
11. Water level indicator.
12. Adjustable rheostat.
13. Servomotor.
14. Copper-oxide rectifier.
15. Remote control switch.
16. Electro-thermal reset device.
17. Thermocouple.
18. High speed thermocouple.
19. High speed thermo-electric pile.
20. Magnetic starter.
21. Impulse tube.

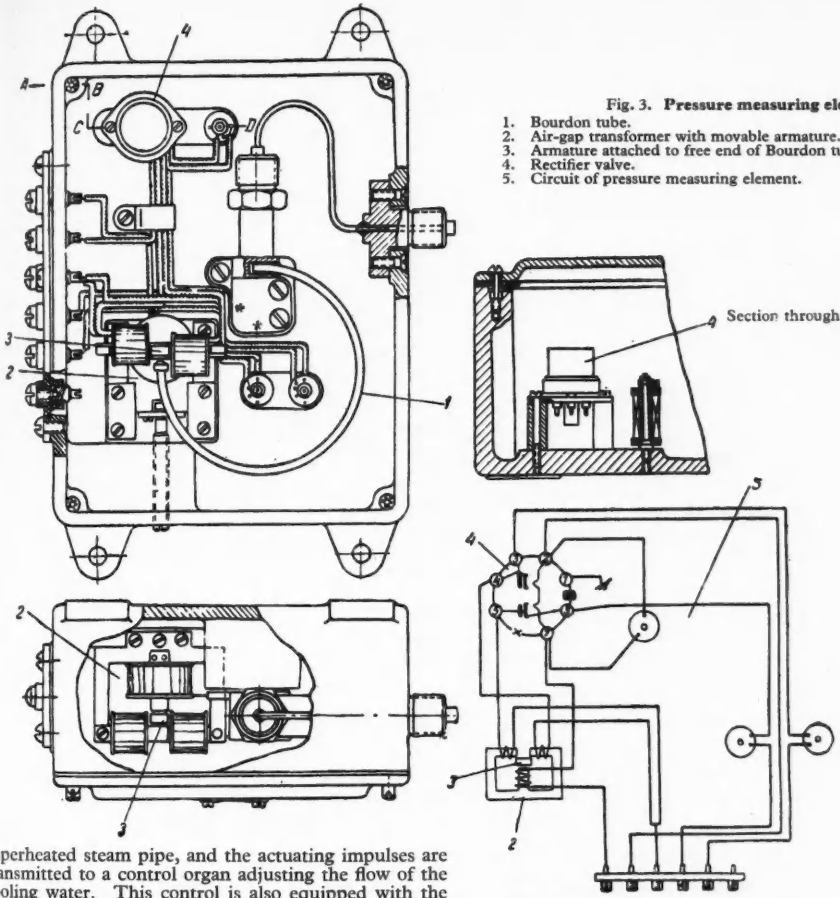

Fig. 3. Pressure measuring element.

1. Bourdon tube.
2. Air-gap transformer with movable armature.
3. Armature attached to free end of Bourdon tube.
4. Rectifier valve.
5. Circuit of pressure measuring element.

superheated steam pipe, and the actuating impulses are transmitted to a control organ adjusting the flow of the cooling water. This control is also equipped with the thermo-electric reset device referred to above.

The feed flow control gear employed in once-through boilers for controlling the steam temperature before the superheater is equipped with both a thermo-electric reset device and a special thermo-pile mounted at the outer end of a tube projecting into the gas flow through the boiler in the superheater zone. Owing to the short length of this tube and the small water flow passed through it, the temperature of the tube follows the variations in flue gas temperature with a minimum of delay. The reduction in the lag of the control system hereby achieved acts to decrease steam temperature variations, as well as to stabilize the control process. The second superheat control is concerned with the control of the steam temperature at the superheater outlet by means of a spray type de-superheater. This control is likewise equipped with a thermo-electric reset device. The component parts of the pressure measuring element can be seen in Fig. 3. The manometer is of the Bourdon tube type, its free end carrying the armature of an air gap transformer with balanced secondary windings. The secondary transformer windings are connected to a copper-oxide rectifier where the induced currents produced by the unbalance of the magnetic circuit are converted into d.c. impulses; these in turn are transmitted to the contact making galvanometer of the chopper bar type which operates the mercury switches. The galvanometer circuit includes the aforementioned thermo-electric reset device.

The servomotor employed to adjust the final control elements such as the controllers of electric motor drives, damper levers, etc., is shown in Fig. 4. Its maximum travel is 360 degrees, that is, one complete revolution. The servomotor comprises a three-phase induction motor of 0·25 KW and a combined reduction and worm gear. By changing the reduction gear, the shaft speed can be changed from $\frac{1}{4}$ r.p.m. to 2 r.p.m. or vice versa. The motor is also equipped with an electro-magnetic brake. The rotation of the shaft is limited by an adjustable stop which releases a mercury switch; this stop may be set at any angle between 30 degrees and 300 degrees. The servomotor operating the fuel feed control of once-through boilers is controlled by an additional reversing magnetic starter, the operating levers of which are blocked by the steam temperature controller which adjusts the fuel feed in accordance with the temperature of the steam at the superheater inlet. This arrangement prevents short circuiting, if simultaneous impulses of opposite direction are transmitted from the pressure controller and from the fuel feed controller respectively.

The steam temperature controller receives its actuating impulses *via* the contact-making galvanometer from the thermo-couple or resistance thermometer installed in the steam main, and it actuates the servomotor which controls the water supply to the de-superheater. This

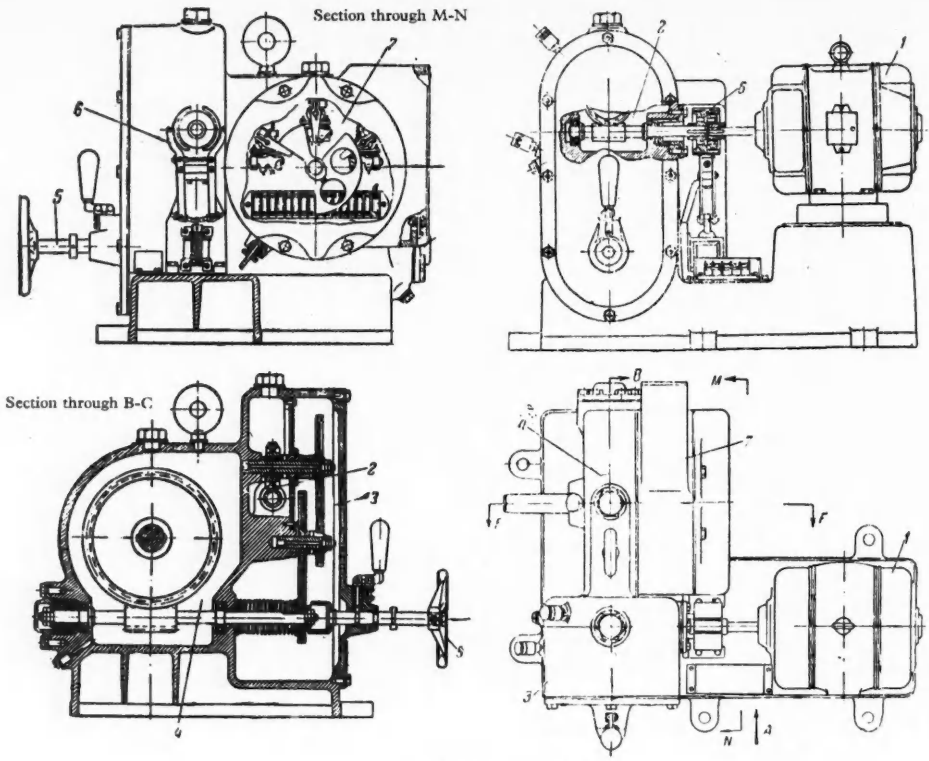

Fig. 4. **Servomotor.**

1. 0·25 KW motor.
2. First worm gear.
3. Second worm gear.
4. Housing of speed reducer gear.
5. Hand wheel.
6. Electromagnetic brake.
7. Stop contacts.

controller is also equipped with a thermocouple. The two thermocouples may be arranged in series or in parallel and the controller will be actuated in accordance with the mean of the indications of the two thermocouples.

The thermo-electric pile which measures the gas temperature at the inlet of the superheater zone is illustrated in Fig. 5. It consists of 25 nichrome-constantan couples. The one group of junctions is insulated against the tubular casing by a thin mica foil, while the other group is insulated by asbestos. When the gas temperature is steady both groups of junctions will be at an identical temperature, and the resultant electro-motoric force will be zero. But if the gas temperature undergoes a rapid change, the temperature of the first group of junctions will change more rapidly than that of the second group, and the electro-motoric forces of the two groups will cease to balance each other. If the equilibrium conditions of boiler operation are disturbed, as, for instance, by stoppage of a coal feeder, the gas temperature will change with sufficient rapidity to produce a resultant electro-motoric force at the thermo-electric pile, and the contact-making galvanometer will therefore transmit a control impulse to the servomotor controlling the rate of fuel feed. But the thermo-electric reset device will also go into action and return the pointer of the galvanometer into the neutral zone. But if the reset device is not able to return the galvanometer pointer into the neutral zone or into the zero position, then the control cycle will be repeated until the proper fuel/water ratio is re-established.

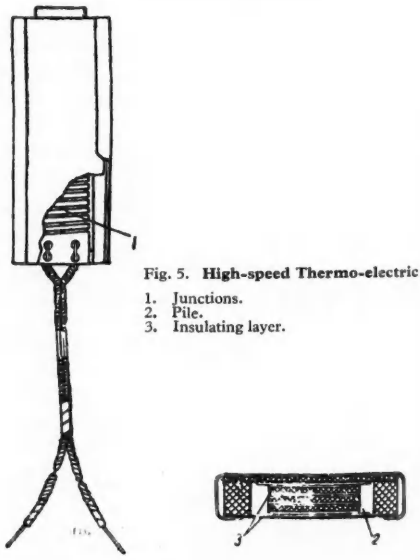

Fig. 5. **High-speed Thermo-electric pile.**

1. Junctions.
2. Pile.
3. Insulating layer.

NEW HIGH-COERCIVE ALLOY "MAGNICO."

By A. S. Zaimovski and L. M. Lvov. (From *Stal*, No. 4, 1945, pp. 115-120, 13 illustrations.)

The employment of the iron-nickel-aluminium alloy Alni containing 23-30 per cent Ni, 12-16 per cent Al, and 3-5 per cent Cn as material for permanent magnets had led to the almost complete elimination of the cobalt steels. The possibility of using this alloy for the high coercive force of 500-600 Oersted in a number of cases is precluded by its low residual induction (5000-6000 Gauss). Attempts have therefore been made of late to find an alloy which combines a high coercive force with high residual induction. The results obtained in this direction form the substance of this article.

The use of chromium, tungsten, molybdenum, vanadium, niobium, copper and silicon in the Alni alloy did not lead to the desired result. The only alloying element which exerts a favourable influence in the desired direction proved to be cobalt. As early as the nineteen-twenties martensitic cobalt steels were being produced. Fig. 1, which is based upon the investigation of the authors, shows the influence of the cobalt content upon the H_c and B_r values of chromium-tungsten steels. As will be seen from this graph, the cobalt content is practically without influence upon the residual induction; while at the same time the coercive force increases in proportion to the cobalt percentage. This relationship can be expressed mathematically by $H_c = H_{Co}\ (1+K \cdot P\ Co)$ where according to Fig. 1 it is $K = 4{\cdot}5$ Oersted per per cent cobalt.

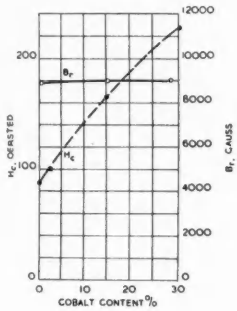

Fig. 1. **Influence of cobalt content upon H_c and B_r of chromium-tungsten steel.**

The remarkable characteristic of cobalt to increase the coercive force without impairing the residual induction appears to be due to two specific properties. In the first place, cobalt is the only element which increases the magnetic saturation of iron. Secondly, cobalt, by entering into the crystal lattice of iron, acts to decrease the lattice parameter, thereby causing a sharp increase in internal tension of the submicroscopic crystalline lattice whenever the lattice, for some reason, undergoes deformation. From a first series of tests it was found that the introduction of cobalt into an Alni s eel with 23-28 per cent Ni and 13-16 per cent Al does not bring about the desired result, the cobalt increasing, as it does, the coercive force, but at the same time lowering the residual induction.

The same result obtained when the nickel content was increased to 30-34 per cent and 1 per cent silicon or 9 per cent were added. The authors then produced a number of alloys containing from 8-13 per cent aluminium, 15-21 per cent nickel, and up to 12 per cent cobalt. The influence of the cobalt content is shown in Fig. 2, where it will be seen that cobalt acts in the same way as it does in hardened martensitic steels, that is to say, it increases the coercive force and has comparatively little influence upon the residual induction. Alloys of the Alnico type containing 20-22 per cent nickel, 12-13 per cent aluminium, and 5 per cent cobalt represent a notable advance over the Alni type, their total energy being some 10-15 per cent higher than that of the Alni type and their residual induction being as high as 7500 gauss.

By increasing the cobalt content to 12 per cent and introducing 6 per cent copper, the properties of the ordinary Alni alloy are improved to such an extent as to allow a reduction in the nickel content to 16-17 per cent, and in the aluminium content to 10-11 per cent. Alloys of this type have been investigated on a commercial scale by Professor Livshits. His findings are charted in Fig. 3, which shows that a residual induction of 6950 gauss was obtained, while the coercive force was 540 Oersted, and the total energy was 63,000 erg/cu.cm. A further increase in the cobalt content to 20-25 per cent in the Alni alloy did not seem to be justified insofar as the 10-20 per cent increase in residual induction and total energy was only obtained by doubling the cobalt percentage.

New possibilities, however, were opened up by treating Alni alloys in the magnetic field. This kind of treatment, of course, is not novel, and has, for instance, been applied with good success to Permally at the Bell Company Laboratories. The authors investigated the magnetic treatment of nickel alloys of 66 and 78 per cent Ni content and found that the permeability could be increased to 350,000 Gauss/Oersted, obtained by quenching in the usual way. The advantages accruing from magnetic treatment are :

(1) High Curie point, that is, a higher temperature of incipient diffusion which in Alni alloys is the cause of a high coercive force.

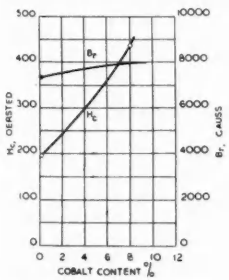

Fig. 2. **Influence of cobalt percentage upon the magnetic properties of Alni steel with 19 per cent Ni and 12 per cent Al.**

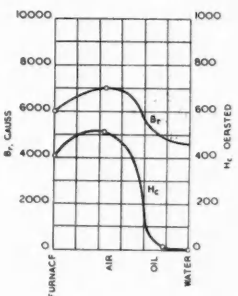

Fig. 3. **Variation in magnetic properties of 6 per cent Cu Alnico steel with rate of cooling from 1250 deg. C**

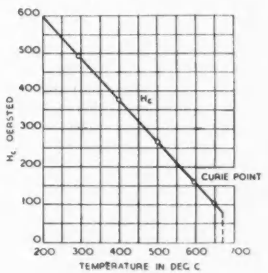

Fig. 4. **Influence of temperature upon coercive force of Alni steel.**

(2) No excessive growth of the coercive force, since, under the influence of a strong magnetic field, the magnetic forces possess the maximum resistance against the disorientating action of the diffusion process. Nickel and cobalt have different effects upon the Curie point of iron. Nickel depresses the Curie point, while cobalt is the only material which increases the Curie point of iron. This is of particular importance in the magnetic treatment. In order to assess the state of total energy of an Alni alloy immediately below the Curie point, the authors determined the inter-relationship between temperature and coercive force of a 27 per cent nickel-13 per cent aluminium alloy. This relationship is charted in Fig. 4, showing that, at 700 deg. C., that is, immediately below the Curie point, the material still possesses a coercive force of 100 Oersted. This is an unfavourable factor from the aspect of the magnetic treatment. In the case of critical cooling speed high coercive force exists in the Alni alloys in the temperature range of 700-750 deg. C.

As was to be expected, attempts to apply the magnetic field treatment to Alni alloys were without success. Experiments were then made with a series of alloys containing 26 per cent nickel and 13-15 per cent aluminium. The intensity of the magnetic field during the critical cooling rate was increased to 10,000 Oersted; and even so, the best result that could be obtained was an increase in residual induction by 5 per cent with the coercive force remaining constant. Somewhat better results were obtained with an alloy containing from 20-21 per cent nickel and 11-12 per cent aluminium. In this case an increase in residual induction by 10-15 per cent at a coercive force of approximately 200 Oersted was registered. But this result, of course, is without practical value.

Data regarding the treatment of Alnico in the magnetic field were first published by Oliver and Shadden in 1938. Magnetic treatment in a field of 4,000 Oersted of an alloy containing 12 per cent cobalt, 6 per cent copper, 10 per cent aluminium, and 18 per cent nickel led to an increase in residual induction by 10 per cent with the coercive force remaining unchanged at 520 Oersted. The magnetic energy was increased by 20 per cent, which is explained by the application of the thermo-magnetic treatment. Samples of Magnico containing 12 per cent cobalt and measuring 20-30 mm. square were investigated in order to determine the properties of this material with regard to its applicability to magnetos and other apparatus of this kind. The results are given below:

TEST RESULTS OBTAINED ON MAGNICO ALLOY WITH 12 PER CENT COBALT.

	Without magnetic treatment	With magnetic treatment	Alni
Residual induction ..	6,950	8,000	6,500–5,500
Coercive force ..	540	520	450– 550
Magnetic Energy erg/cu.cm.	63,000	75,000	50,000

From these data it will be seen that the magnetic properties of 12 per cent Magnico alloy can be made to exceed the corresponding properties of Alni by 50 per cent, and this offers considerable advantages when used as material for magnetos, electric generators, etc. The investigations made by the authors showed that cobalt sharply decreases the critical cooling rate—that is, it retards the creation of high coercive forces and favourably influences the effects of the magnetic-field treatment.

Fig. 5 shows the relationship between the coercive force and the cooling rate both of an Alni alloy containing 27 per cent nickel and 15 per cent aluminium and an Alnico alloy with 27 per cent nickel, 15 per cent aluminium, and 10 per cent cobalt, as investigated by the authors. As will be seen from this graph, the

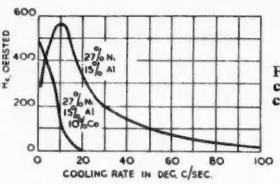

Fig. 5. **Influence of cobalt percentage upon critical cooling rate of Alni steel.**

critical cooling rate producing maximum coercive force is greatly shortened by the presence of 10 per cent cobalt in the alloy.

According to a patent granted to the Philips concern in 1940, an alloy with 20-25 per cent cobalt with greatly lowered nickel and aluminium percentages exhibits, upon treatment in the magnetic field, an increase in residual induction by 60 per cent and in magnetic energy by 185 per cent. In view of these statements, the authors undertook the study of an alloy containing 13·5 per cent nickel, 8·0 per cent aluminium, 24·0 per cent cobalt, and 3·0 per cent copper. The casting properties of this alloy were practically the same as those of the Alni alloy, and castings ranging from 1-2 grams to several kilograms in weight could easily be made. The mechanical properties of the alloy were also found to be identical with those of the Alni material. The material could be machined only by grinding.

A first series of tests was concerned with cooling the test pieces from 1250 deg. C. at different speeds in order to compare the properties of the material with those of the Alni alloy. Cooling from 1250 deg. C. to 500 deg. C. at various speeds was carried out in the following ways: (1) furnace cooling; (2) cooling in a wrapper of asbestos; (3) cooling in still air; (4) cooling in boiling water.

The cooling rate was ascertained by directly measuring the temperature of the test pieces by means of thermocouples. Fig. 6 shows the variation in coercive force H_c and in residual induction B_r with the logarithm of the cooling rate, the latter being determined in a special way referred to below. This graph shows that, while a residual induction of 11,000 gauss is reached, the coercive force is only 300 Oersted. A material of this type has therefore no practical significance.

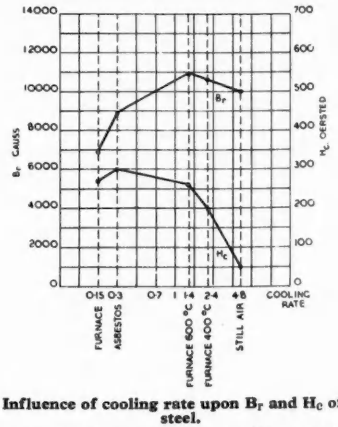

Fig. 6. **Influence of cooling rate upon B_r and H_c of Magnico steel.**

In order to obtain optimum cooling speed—that is, the critical speed—a special tubular furnace, designated "Furnace No. II," of sufficiently large mass, was built. By heating the test pieces in Furnace I and transferring them to Furnace No. II, they can then in the latter be heated to 1300 deg. C., and can subsequently be cooled at the required rate. In these tests the specimens were

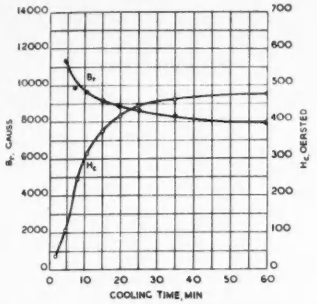

Fig. 7. **Influence of cooling rate in furnace No. II (to 600 deg. C.) upon B_r and H_c of Magnico steel.**

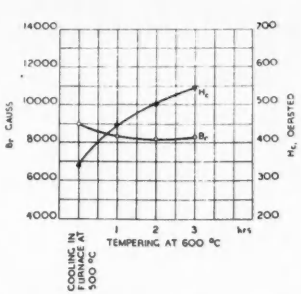

Fig. 8 **Influence of tempering time (at 600 deg. C.) upon B_r and H_c of Magnico steel, cooled in furnace from 1300 to 500 deg. C.**

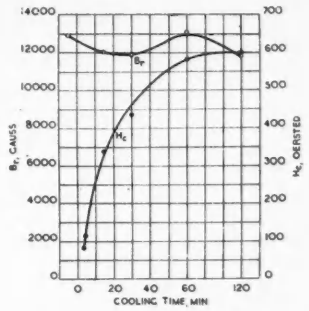

Fig. 9. **Influence of time of cooling to 600 deg. C. upon the magnetic properties of Magnico steel.**

cooled, with the temperatures of Furnace No. II being held at 300, 400, 500 and 600 deg. C. respectively. From the resultant magnetic properties it was found that the optimum temperature of Furnace No. II ranged from 500 to 600 deg. C. The test results obtained with 600 deg. C. are charted in Fig. 7, where it will be seen that B_r and H_c values registered are higher than the corresponding values obtained after cooling in air or in asbestos packing. The B_r and H_c values given in Fig. 6 were obtained in Furnace No. II by cooling to 600 deg. C. within 10 minutes, which is too short a cooling period. But even when extending the cooling period to its optimum value, the resultant coercive force only approximated to H_c = 500 Oersted, and the residual induction to B_r = 8000 gauss, which can hardly be considered satisfactory.

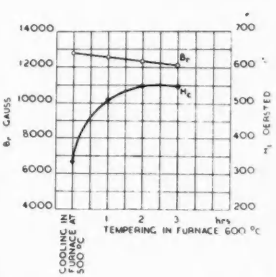

Fig. 10. **Influence of length of tempering at 600 deg. C. upon magnetic properties of Magnico steel after cooling in furnace No. III from 1300 to 500 deg. C. in magnetic field.**

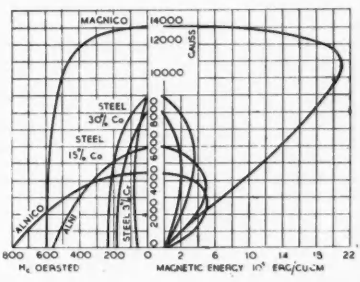

Fig. 11. **Comparative magnetic characteristics of Magnico, Alni, Alnico, chromium and cobalt steels.**

By cooling to 500 deg. C. still less satisfactory values for H_c and B_r were obtained. However, by tempering at 600 deg. C., H_c improved to 550 Oersted and B_r to 8400 gauss, as shown in Fig. 8. In order to be able to carry out the cooling process in a magnetic field, a third furnace (Furnace No. III) was then constructed. This furnace is similar to Furnace No. II, but was designed to fit between the poles of an electromagnet, permitting the production in the furnace of a magnetic field of 4500 Oersted over a length of 100 mm. The magnetic treatment was carried out in the following manner: After heating to 1300 deg. C. in Furnace No. I, the test piece was transferred to Furnace No. III in which a temperature of 600 or 500 deg. C. respectively was maintained. After that, Furnace No. III was placed, without delay, between the poles of the electromagnet.

The results obtained by cooling the test piece to 600 deg. C. in the magnetic field in 60 minutes are charted in Fig. 9, which shows that an exceptionally high residual induction of 13,000 gauss and a coercive force of 600 Oersted were reached, the maximum total energy amounting to 180,000 erg per cu.cm. This treatment in fact represents a quench with subsequent tempering at 600 deg. C. Actually, by tempering the test piece once more at 600 deg. C. subsequent to the cooling process in the magnetic field, somewhat better results were achieved. By carrying out the magnetic treatment with cooling to 500 deg. C. and then tempering at 600 deg. C., a residual induction of approximately 12,500 gauss and a coercive force of 550 Oersted were reached, as shown in Fig. 10.

It is necessary to point out that the B_r and H_c values as such do not fully represent the maximum magnetic energy attainable with Magnico. The maximum magnetic energy obtainable with Alni subjected to magnetic treatment can be approximated by the expression

$$BH_{max} = 0{\cdot}38 - 0{\cdot}4\ B_r \times H_c$$

while for Magnico the corresponding expression reads

$$BH_{max} = 0{\cdot}7\ B_r \times H_c.$$

This fact is of great practical significance, since with Magnico not only the true residual induction in the closed magnetic circuit is increased, but the induction is also increased under conditions such as obtain in magnetic circuits encountered in actual practice. Magnico therefore possesses exceptionally high magnetic qualities, its magnetic energy being four times that of Alni and 22 times that of ordinary chromium steel. The magnetic characteristics of the various materials are compared in Fig. 11, which also includes two cobalt steels.

Tabulated values of the magnetic properties are given below.

PROPERTIES OF MAGNETIC MATERIALS

	3% Cr-steel	15% Co-steel	30% Co-steel	Alnico 25% Ni 15% Al	Alnico 34% Ni 14% Al 1% Si	Magnico magnetically treated, 24% Co
Coercive force Oersted ..	60	170	220	550	800	580
Residual induction Gauss	9,000	8,000	9,000	5,500	4,200	13,300
Magnetic energy erg per cu.cm.	9,000	22,000	35,000	50,000	55,000	200,000
Relative weight per unit of energy ..	22	8·8	5·7	4·0	3·7	1·0
Optimum ratio length/cross section ..	12	4	3	1·3	0·9	3·0

RUSSIA

THE PROBLEM OF FLAMELESS COMBUSTION.

By H. N. JUDYAKOV and V. S. PUSHKIN. (From *Izvestya Akademi*, Nank, USSR. No. 6, 1945, pp. 545-553, 6 illustrations.)

THE fact that despite many investigations, the flameless combustion process has not found much practical application is explained by the difficulties encountered in attempts to apply this combustion principle to boiler furnace technique. Also, this problem has so far failed to attract the attention of combustion engineers in general, and of others interested in power generation, since there has prevailed a general tendency to underestimate the fact that flameless combustion will eventually prove an important factor in reducing the size of stationary as well as of marine boiler furnaces.

Since the authors were convinced of the great practical importance of the method of flameless combustion, they undertook to investigate the maximum combustion rates that can be reached with the firing of naptha gas in combustion ducts filled with granular refractory brick or corundum.

The first part of the investigation was concerned with the determination of the critical velocity at which, for different fuel/air ratios, the maximum permissible heating load is reached for the refractory material. In the second part of the investigation the minimum rate at which combustion can be maintained was determined. This minimum rate was defined as the combustion rate at which flameless combustion ceases.

The experiments were carried out with the burner shown in Fig. 1, in which is seen a burner nozzle of refractory material inserted in a water-cooled burner duct. The granular filler must possess a high degree of refractoriness, as the flameless combustion process takes place with a very intensive development of heat. Also the filler must possess high and uniform porosity in order to keep the pressure drop small.

Fillers of different fractions with maximum particle sizes of 1, 2, 3, 4, 5, 6, 7 and 8 mm. were tried. At the same time the porosity was kept constant regardless of the particle size, the porosity amounting to 52 per cent in the case of fire brick particles, and to 49 per cent in the case of corundum particles. In one series of test runs the burner duct was filled with loose granular material, while in a second series the granular material was sintered.

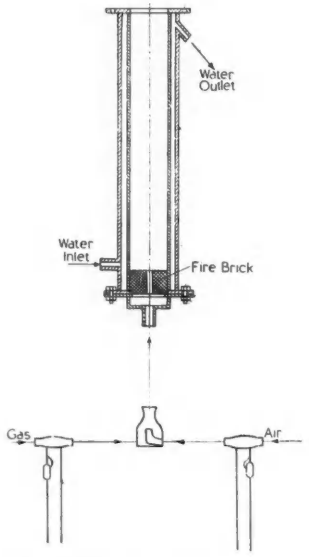

Fig. 1. **Diagram of experimental installation.**

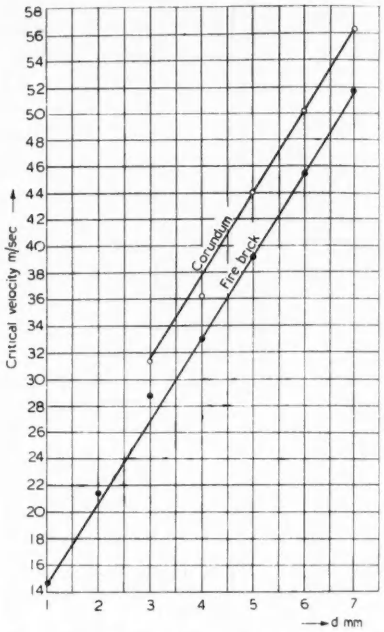

Fig. 2. **Variation of critical flow velocity with particle size of filler.**

The first series of tests is of particular interest insofar as the preparation of the loose granular material is much simpler than the preparation of the sintered fillers. The loose material, however, was found to possess the disadvantage that with a certain range of gas velocities the uniformity of porosity was disturbed, the smaller particles being transported to the end (top) of the burner duct, where they were entrained in the gas stream and carried off. The ensuing depletion of the filler of small particle sizes results in a considerable drop in the frictional resistance of the filler, so that the flame emerges from the filler and puts the apparatus out of commission. The limiting gas velocities observed by the authors are charted in Fig. 2 as functions of the particle size. The experiments were carried out with naphta gas of a calorific value of 10,700 cal. per cu.m., the products of combustion containing 11·05 per cent CO_2, 71·8 per cent N_2, and 17·15 per cent H_2O. The test results are charted in Figs. 3, 4 and 4a.

From Fig. 3 it will be seen that a linear relationship exists between the rate of maximum heat release and the particle size. The relationship between the maximum heat release and the particle surface area is charted in Figs. 4 and 4a, which show that the maximum rate of heat release increases progressively with the particle surface area. Thus, for instance, a surface area corresponding to a particle size of 2 mm. is coordinated with a maximum rate of heat release of 20,000 cal. per cu.m./hr.; while the surface area corresponding to a particle size of 6 mm. is coordinated with a rate of heat release of 135,000 cal. per cu.m./hr.

The next step consisted in investigating three burner

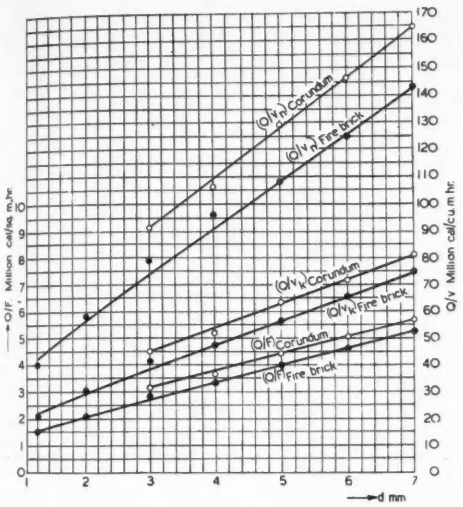

Fig. 3. **Thermal load data.**

Q/V_n = rate of heat release per cu.m. of void in filler, million cal. per hour.

Q/V_k = rate of heat release per cu.m. of filler, million cal. per hour.

Q/F = rate of heat release per sq.m. of burner area, million cal. per hour.

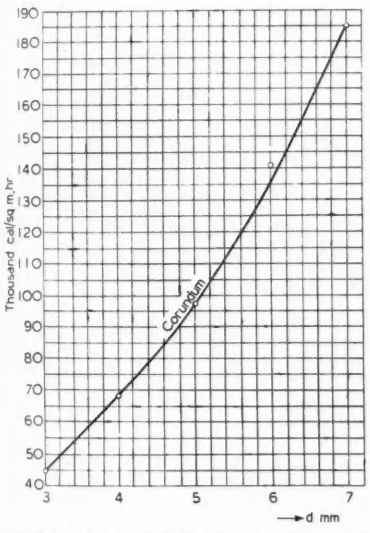

Fig. 4. **Rate of heat release Q/F_3 in thousand cal. per sq.m. of particle surface area, per hr. (Corundum filler.)**

tubes of 32 mm., 48 mm., and 105 mm. diameter respectively. In order to prevent back firing, the diameter of the respective burner nozzles was so chosen that the velocity in the nozzle at minimum gas flow remained greater than the speed of flame propagation. For this reason the 32 mm. tube was fitted with a nozzle of 5 mm. diameter, the 48 mm. tube with two nozzles of 5 mm. diameter each, and the 105 mm. tube with 4 nozzles of 5 mm. diameter each. The temperature of the products of combustion at the outlet of the burner tube was measured by means of a thermocouple, and the air and fuel flow were determined by means of flow meters fitted into the respective supply lines. The naphta gas had the following composition :—

CO_2	.. ..	2·0 per cent.
C_2H_6	.. ..	5·0 „ „
C_3H_3	.. ..	10·0 „ „
CH_4	.. ..	50·0 „ „
C_4H_{10}	.. ..	10·0 „ „
H_2	.. ..	15·0 „ „
CO	.. ..	8·0 „ „

while the products of combustion were found to be composed of :—

CO_2	.. ..	11·05 per cent.
H_2O	.. ..	17·5 „ „
N_2	.. ..	71·45 „ „

The temperature of the cooling water supplied to the jacket of the burner tube was measured at inlet and outlet by means of measuring thermometers, while the rate of flow was measured by means of a calibrated vessel. All three burner tubes were of the same length (340 mm.) and the height of the active refractory filler was 70 mm. In order to investigate the influence of the height of the filler upon the combustion process, tests were run with the active filler alone as well as with a completely filled tube, superimposing a top-filler of fire brick of 9 mm. particle size over the active filler proper. The variation in temperature over the length of the burner tube was measured by means of 4 platinum platinum-rhodium thermocouples placed centrally in the tube at different heights. In order to prevent catalytic action of the metal of the thermocouples, the

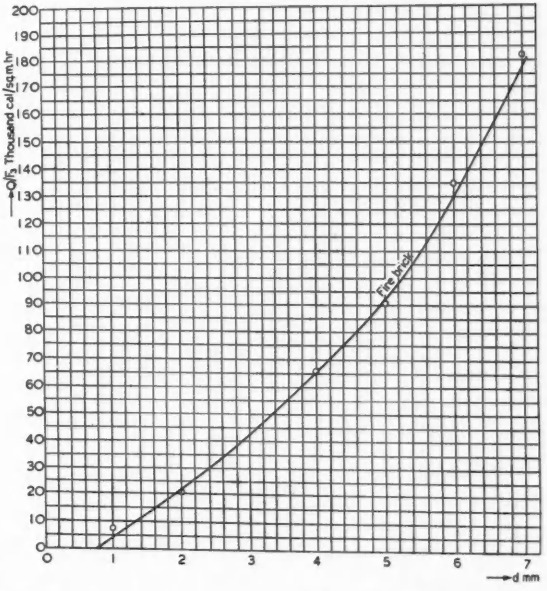

Fig. 4a. **Rate of heat release Q/F_3 in thousand cal. per sq.m. of particle surface area, per hr. (Fire brick filler.)**

latter were encased in porcelain tubes. In all the tests conducted with the three burner tubes, an active filler of corundum of 9 mm. maximum particle size was used, as a firebrick filler had proved to be subject to rapid waste. A top filler of firebrick of 9 mm. maximum particle size was used throughout.

The influence of the top filler upon the efficiency of the flameless burner is exemplified by the test data obtained with the 48 mm. diameter burner tube.

Burner tube No. 2, 48 mm. dia.

With top filler.

Naphta gas firing rate, litres/min.	4·2	4·5	5·2	5·9
Combustion air, litres/min.	49·0	53·0	61·0	70·0
Burner efficiency, per cent	68·0	70·5	77·6	—

Without top filler.

Naphta gas firing rate, litres/min.	4·2	4·5	5·3	6·3
Combustion air, litres/min.	49·0	53·0	63·0	74·0
Burner efficiency, per cent	55·7	56·0	64·0	64·5

The variations in temperature over the length of the burner tube are charted in Figs. 5 and 6. Fig. 5 refers to a burner without top filler and Fig. 6 to the same burner with top filler. A comparison of these two temperature characteristics shows that the presence of the top filler lowers the temperature in the zone of highest temperatures at least by 100 deg. C., while progressively greater temperature reductions are obtained towards the outlet of the burner. In either case the highest temperature was recorded in the active layer at a height of some 45-50 mm. where the combustion proper takes place. At a height of some 70 mm. the combustion process was found to be completed.

The experiments showed that flameless combustion cannot be maintained in burner tubes of less than 32 mm. diameter, as the cooling effect becomes excessive. In this case combustion takes place at the outlet of the burner tube, and it was found quite impossible to make the flame descend into the filler at any firing rate even when the tube was completely filled with refractory filler. The maximum firing rate that could be achieved with the 32 mm. diameter burner tube was 2 litres of naphta gas per minute.

The maximum rates of heat release obtained with the 32, 48 and 105 mm. diameter burner tubes are as follows :—

Burner Size.

Rate of heat release.	32 mm. dia.	48 mm. dia.	105 mm. dia.
Q/V_k = cal. per cu.m. of filler, per hr.	$22{\cdot}9.10^6$	$25{\cdot}1.10^6$	$11{\cdot}65.10^6$
Q/V_n = cal. per cu.m. of void in filler per hr.	$46{\cdot}7.10^6$	$51{\cdot}3.10^6$	$23{\cdot}8.10^6$
Q/F = cal. per sq.m. of burner area, per hr.	$1{\cdot}6.10^6$	$2{\cdot}24.10^6$	$0{\cdot}817.10^6$
Q/F_s = cal. per sq.m. of particle surface area, per hr.	$67{\cdot}3.10^3$	$74{\cdot}1.10^3$	$27{\cdot}8.10^3$

These data show that an increase in the burner area by 50 per cent results in an increase in the rate of heat release per sq.m. of burner area by 40 per cent, while the rates of heat release based upon the particle surface area and upon the void space in the filler increase by approximately 10 per cent.

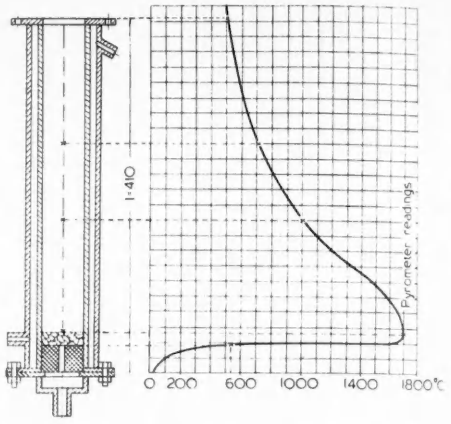

Fig. 5. **Temperature distribution in burner tube without filler.**

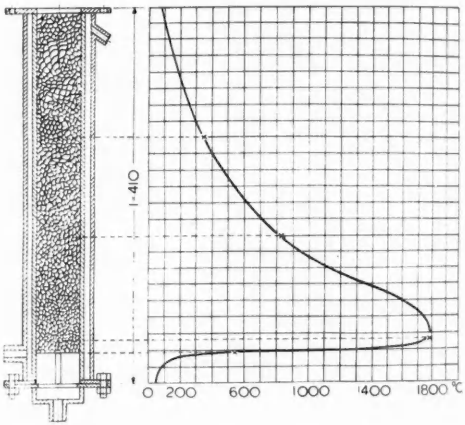

Fig. 6. **Temperature distribution in burner tube with filler.**

RUSSIA

A PNEUMATIC MILL DEVELOPED BY THE ALL-UNION THERMO-TECHNICAL INSTITUTE.

By M. L. KISELHOF. (From *Izvestya Vsesoyuznogo Teplotechnickeskogo Instituta*, No. 1, January, 1946, pp. 5-11, 12 illustrations.)

THE first full-size pneumatic mill of the type designed by the author was installed in 1944 at the No. 9 Mozenergo plant to operate in conjunction with the 100 t/hr. Loeffler boiler installed at that plant. This mill has a capacity of 27 t/hr. sized Lower Moscow coal with an average moisture content of 33 per cent. The upper size of the coal is 20 mm. The Loeffler boiler is also equipped with a Pfeiffer ball mill of similar capacity. The plant layout is shown in Fig. 1, and the salient dimensions of the pneumatic mill are given in Fig. 2. From Fig. 1 it will be seen that the raw fuel is supplied to the pneumatic mill from the weighing hopper (1) via a belt-type conveyor and a chute (3), the latter discharging into the dispersing tube (4). In order to avoid excessive aspiration of air with the fuel, two rotary air lock valves are provided in the feeder line.

The pneumatic mill proper consists of the collector (5) in which foreign particles are collected, the dispersal tube (4), the grinding chamber (6), the classifier (7), and the return feed (8) driven by a 1·7 kW. motor.

The fuel introduced into the dispersal tube is exposed to a stream of hot gases which effects the dispersal of the fuel particles, ejects them from the nozzle (9), and causes them to impinge upon the impact plate or anvil (10), hereby effecting their disintegration. Disintegration of the fuel particles by mutual impact and

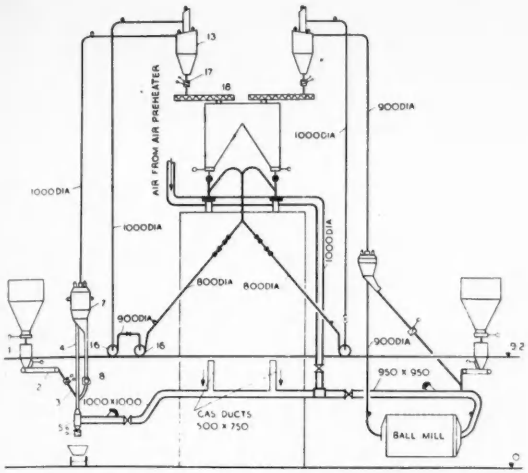

Fig. 1. **Pulverized coal preparation plant for Loeffler boiler.**

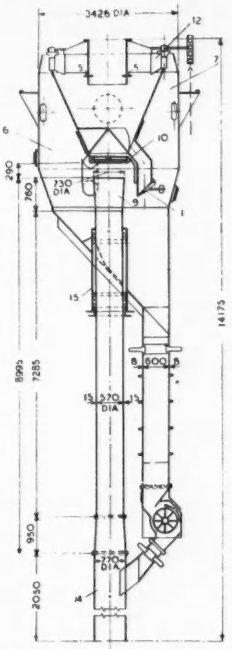

Fig. 2. **Pneumatic mill of 27 ton/hr. capacity.**

by friction with the tube walls also takes place in the dispersal tube. After impingement upon the impact plate the fuel is subjected to a double separating effect, the first effect taking place in the grinding chamber where the coarse fractions are extracted from the gas stream and returned to the bottom inlet of the dispersal tube. The second separating effect is carried out in the conical space of the cyclone located on top of the impact plate. The coarse fractions are rejected from the cyclone through three nipples closed by flap valves and discharging into the space of the first separator, from whence the coarse fractions are returned to the bottom inlet of the dispersal tube. The second separator is equipped with inlet vanes which permit the adjustment of the fineness of the final product. The latter is passed from the second separator to the cyclone (13) (Fig. 1), and finally into the storage bunker.

In order to ensure entrainment of the coarse particles of the raw coal, the first section of the dispersal tube (14) of the mill (Fig. 2) is laid out for a gas velocity of 47 m/sec. This section of the dispersal tube serves for the separation of foreign matter contained in the coal or accidentally mixed up with it.

The diameter of the dispersal tube is based upon an average gas velocity of 65 m/sec., while in the topmost diffuser the gas velocity is decreased to 30 m/sec. The distance between the impact plate and the diffuser outlet is 0·4 times the diameter of the diffuser. Where this is required for special reasons, the dispersal tube may be extended up to 9 m. instead of the length of 5·25 m. actually required; but this increases the gas flow resistance of the dispersal tube by 15 per cent. As the lower part of the dispersal tube and the separator are bolted to the boiler structure, an expansion joint (15) is provided in order to take up the thermal expansion. The impact plate is made of armour plate of 60 mm. thickness. The gas-air mixture employed in the dispersal tube as drying and entraining medium has an initial temperature of 650 deg. C., and it reduces the moisture content of the coal from 35 to 15 per cent. The required gas velocity is produced by two suction fans (16) designed for a delivery of 48,000 cu. m./hr. at 70 deg. C. against a static head of 1·85 m. w.g. The fan drives are of 300 kW. and 340 kW. capacity respectively.

The cyclone (13) of 3·25 m. diameter is of standard design. The pulverized fuel collected in the cyclone is passed to the screw conveyor (18) through an air lock consisting of two rotary valves (17). The pneumatic mill was put into regular operation in February, 1945, after a few initial defects had been eliminated. It has since been in operation for 2,500 hours, grinding 62,350 tons of coal in all.

As mentioned above, the suction fans were designed for a static head of 1·85 m. w.g. Actually the head produced amounts to only 1·65 m. w.g., and the capacity of the mill is therefore approximately 15 per cent below its rated capacity. Furthermore, the optimum efficiency of the fans was found to occur at a higher capacity than planned, namely, at 62,000–70,000 cu.m./hr. capacity instead of at 40,000–50,000 cu.m./hr. delivery. This led to an increase in power consumption of 15-20 per cent above the original estimate.

By appropriate adjustment of the inlet vanes of the separator, practically any required fineness can be obtained. Referring to Fig. 3, it will be seen that with a vane angle of 45 degrees a residue of 10-12 per cent on A.S.T.M. sieve No. 170 obtains; while with angularities of 75 to 90 degrees, the residue amounts to approximately 35 per cent. Very fine pulverization with a residue of less than 10 per cent can be obtained by setting the vanes at an angle of less than 45 degrees.

It should be noted that the wide variation in gas

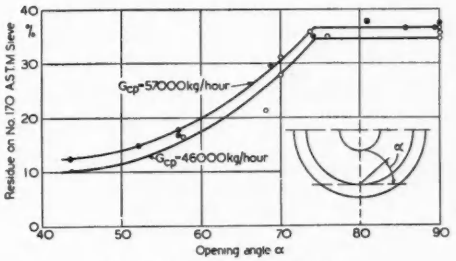

Fig. 3. **Separator characteristic.**

velocity produced by changing the position of the separator vanes had but insignificant influence upon the fineness of the final product. Thus, for instance, with a gas velocity of 47 m./sec., corresponding to a vane position of 90 degrees, the residue amounted to 35 per cent on No. 170 A.S.T.M. sieve; while with a gas velocity of 70 m./sec. a residue of 36·7 per cent was recorded.

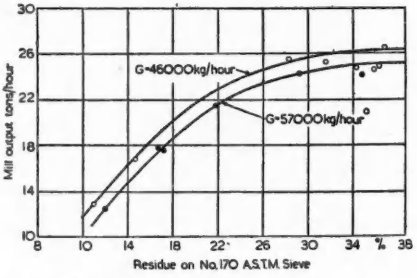

Fig. 4. **Mill output *versus* fineness of final product.**

The mill output is determined by three factors, namely, (1) the degree of fineness of the final product, (2) the rate of fuel feed, or—what comes to the same—the friction loss in the mill, and (3) the amount of gases passed through the mill circuit. As will be seen from Fig. 4, for a given rate of gas flow the mill output rises sharply with increasing coarseness of the final product until a certain maximum output is reached. But this graph also shows that with a gas flow of 46,000 kg./hr., the output is actually some 1–1·5 t/hr. longer than with a gas flow of 57,000 kg./hr. This is explained by the fact that the static pressure at the fan delivery decreases with a rising rate of delivery. Fig. 5 shows the relationship between the flow resistance in the mill and the mill output for different percentages of residue, the rate of gas circulation being kept constant for any given percentage. According to the characteristics shown the rate of output mounts steeply with the flow resistance. Thus, for instance, with a residue of 34 per cent the mill output amounts to 21·3 t/hr., if the mill resistance is 1·0 m. w.g., and it rises to 26·3 t/hr. if the mill resistance is increased to 1·25 m. w.g.

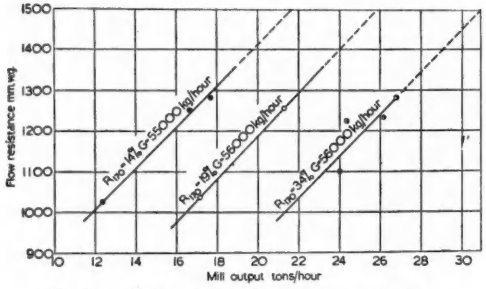

Fig. 5. **Mill output *versus* flow resistance of mill.**

It is therefore safe to conclude that a mill output of 31 t/hr. would obtain if the fans were able to deliver the design head of 1·85 m. w.g., corresponding to a mill resistance of 1·5 m. w.g. The output of the mill must also depend upon the size of the raw coal supplied to it. Referring to Fig. 5, the output of the mill is 26·5 t/hr. if the raw coal leaves a residue of 20 per cent on a sieve of 10 mm. aperture, and the output decreases to 24 t/hr. if the residue is increased to 35 per cent.

The characteristic of the specific power consumption of the mill is charted in Fig. 6, which shows that the specific power consumption increases with the rate of

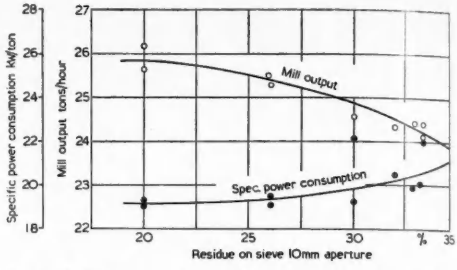

Fig. 6. **Mill output and specific power consumption *versus* initial size of coal.**

gas flow through the mill. In order to achieve minimum specific power consumption the mill should be operated with the smallest possible rate of gas flow. With regard to the specific power consumption recorded for the present installation, it must also be noted that the actual efficiency of the suction fans is only 46 per cent instead of 55 per cent as originally estimated. If the latter figure had been obtained, a specific power consumption of 16 KW./ton of final product would be required instead of the actual figure of 19 KW./ton.

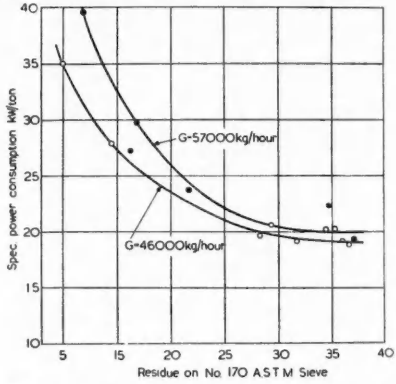

Fig. 7. **Specific power consumption *versus* fineness of final product.**

In the pneumatic mill drying and grinding of the fuel are simultaneous processes, and for a given initial moisture content the drying action will be governed by the concentration of the fuel in the gas, that is, the fuel-to-air ration, as well as by the initial gas temperature. Test results showed that with an initial moisture content of 30·9 per cent and a fuel/gas ratio of 0·4, the moisture content of the final product was 13·5 per cent. In this case the temperature of the air-gas mixture at the mill inlet was 483 deg. C. and the temperature at the mill outlet was 64·4 deg. C. The corresponding specific power consumption is given as 19·0 KW hr./ton. By raising the inlet temperature to 540 deg. C. and lowering the fuel/gas ration to 0·206 a final moisture content of 2·5 per cent was achieved, while the specific power consumption was 35·5 KW hr./ton. In this case the initial moisture content was 24 per cent.

The wear of the dispersal tube was found to amount to approximately 1·0 to 1·5 mm. of wall thickness for each 100 hours of operation; while the impact plate showed a loss in thickness of 1·25 mm. for each 100 hours of operation. The total wear of the mill as a whole was found to be 90 grams of metal per ton of coal, which compares favourably with a figure of 300 grams per ton for ball mills.

POWER ECONOMY IN ROLLING MILLS.

By Y. N. SHPUNBERG. (From *Promishlennaya Energetika*, No. 1, 1946, pp. 3-5, 5 illustrations.)

POWER consumption in rolling mills is a very heavy item, and is worthy of far more detailed study than is usually accorded to it. The rolls will account for as much as 30 to 40 per cent of the total power consumption of a steelworks.

Influence of temperature of metal

Fig. 1 indicates how the power *W* taken as 100 per cent at 1250 deg. C. rises rapidly as the temperature drops, particularly for hard steels, while Fig. 2 gives the temperature conditions during rolling. It is all too easy, at some stages, to increase the power consumption by 50 per cent through losing 100 deg. C. This shows the importance of strict control of starting temperatures, and of so planning the process as to reduce cooling to a minimum at all stages.

Influence of correct planning of rolling passes.

From the point of view of power economy it is essential (1) to get maximum deformation during the early stages and ease off as the metal cools, (2) to reduce to a minimum the number of passes, thus shortening the whole process, with the twofold advantage of working hotter metal (power economy) and increased production.

A reduction in the number of runs necessitates increased pressures with a corresponding increase in power consumption per run. But the fact that there are fewer runs at a greatly increased average temperature leads to a large net saving. In a typical case, the reduction from 17 passes to 13 led to a power saving of 20·6 per cent, while the theoretical rise in output of the plant was estimated as 25 per cent. In one particular instance a power saving of 25 per cent was effected merely by replanning the passes.

Speed of rolling

The speed of rolling can often be increased simply by speeding up the rolls without any other alterations. It has the same twofold effect of increasing production and reducing power consumption per ton due to raising the average working temperature.

Elimination of idle time

In addition to the obvious advantage of greater output, the indirect advantage of increased average temperature is most important. In one works a 40 per cent reduction of idle time was effected on one section and 25 per cent on another. The resulting power saving proved to be 32 and 20 per cent respectively. Saving of time can be achieved either by more careful planning or by the introduction of automatic operation.

Friction in bearings

Bearing friction adds to the net energy required for rolling, it amounts to about 20 per cent for sections and 50 per cent for plates. A considerable economy results from switching over from bronze to textolite bearings. In one Russian works this switchover resulted in a power saving of 15 per cent on the blooming mill and 21 per cent on rail sections, while on medium plates the saving was 25 per cent in the first and 50 per cent in the second mill.

Textolite is of greatest advantage for heavy work at high speed, and very low friction results provided plenty of cooling water is used. But it is not applicable to dual sheet mills where temperatures may reach 150 deg. C.

A reduction in friction can also be effected by the use of fluid friction (Morgoil) type of bearing. The quality of the lubricant should also be studied. One steelworks reduced its power consumption by 15 per cent and another by 12 per cent by going over to a better lubricant. Careful adjustment of bearings can give similar results.

Other factors

Water, on an average, accounts for 10 to 12 per cent of the total power used per ton of metal, and if its use is rationalized, considerable economies may result.

D.C. supply machinery

is often used wastefully, and two motor-generators kept running when one would be sufficient.

Normal consumption figures

It is important to apply scientific methods to the checking of consumption. The following points should be observed :—

(*a*) Check the correct planning of the process.

(*b*) Indicate what losses can reasonably be expected and provide for an incentive for greater economy.

(*c*) Make a clear analysis of how and where the power is actually used or wasted.

(*d*) Make fair allowances in terms of kWh/ton for all normal energy requirements of the process including auxiliaries.

At present consumption standards are usually arrived at by either examining statistics of previous overall consumption in kWh/ton or by measuring the consumptions of a few individual units. Both methods amount to no more than a somewhat uncritical acceptance of existing conditions, though the experimental method is capable of giving valuable results if sufficiently extended and detailed—whereupon it becomes too cumbersome to be practical.

The correct and rational approach is a combination of experiment and calculation. The net work required varies enormously with the types of section and the ways of producing them. It is, therefore, impracticable to make measurements in each case and preference should be given to calculation with an occasional check by experiment.

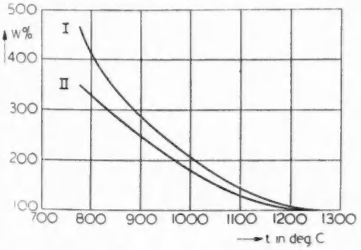

Fig. 1. **Curves of power consumption in rolling against temperature of metal.**
I. 0·36 per cent C steel.
II. 0·15 per cent C steel.

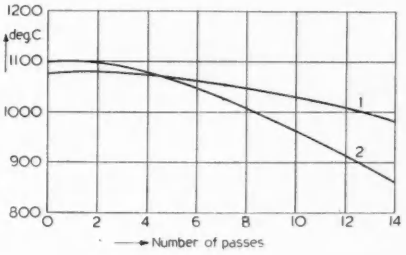

Fig. 2. **Temperature conditions during rolling.**
1. Continuous process.
2. Semi-continuous process.

Idling losses of the mills and the power absorbed by auxiliaries can be determined experimentally. The procedure is as follows :—

(1) Each machine has its idling power P_1 determined under normal conditions and recorded on a "history sheet." This provides a figure against which subsequent periodical measurements can be checked, thus disclosing any deterioration in efficiency.

(2) Net rolling power per ton W_n is calculated for all sections and types of steel likely to be rolled in the various possible ways and this information is recorded graphically.

(3) Power consumption per ton by the rolls is calculated from—

$$W_r = W_n + \frac{P_1 + P_n}{Q}$$

where P_n = average power losses in the electrical machinery and Q = production in tons/hr.

(4) Power consumptions of auxiliaries per ton W_a at the mains is then calculated from records of consumption and production over a representative period.

(5) Total normal consumption is then found as—

$$W = W_r + W_a.$$

(6) Separate values of W (W_1, W_2, W_3, etc.) having been determined for various individual mills and types of product, the total ideal consumption A for the rolling sections of the works can then be obtained each day by multiplying these figures by tonnages of steel produced, thus :—

$$A = W_1a + W_2b + W_3c + \ldots\ldots \text{in kWh.}$$

This figure compared with the actual kWh for the day shows whether there has been waste or economical production.

CZECHOSLOVAKIA

EXPERIENCES AND IMPRESSIONS GAINED IN A JOURNEY THROUGH RUSSIA *

By V. BRUZA, Director, Czechoslovak Ministry for Industry. (From *Strojnicky Obzor*, Vol. 26, No. 5-6, March, 1946, pp. 43-46).

1. PLANNING IN THE U.S.S.R.

IMMEDIATELY after the outbreak of war, all belligerent countries were compelled to introduce a state-planned economy as the only means of mobilising their resources.

The difference, in economic outlook, between the U.S.S.R. and the rest of the world lies in the Soviet Government's conception that the economic life of a state can only be controlled efficiently by a centrally directed economic plan. Without pursuing this aim consistently the Soviet Union could not have achieved that success which had such a decisive influence on the victorious end of the war.

In the U.S.S.R. there is a single centralized body called GOSPLAN—the state planning office—which co-ordinates the planning for the whole state. This body gives all the directives to both the people's commissariats and the committees.

In cases where extraordinary problems are to be solved, a special "Soviet of Experts" is consulted which is composed of the best economists in the Union. The principles and general directives aiming at a planned economy are determined by the government. Planning by the Gosplan is carried out on these lines, and is undertaken with a view to obtaining results within a given period (3-years' plan or 5-years' plan). In working out the preliminary plan there is close co-operation between Gosplan and the people's commissariats. The plan thus worked out is presented to the government, and after ratification becomes law. Some branches of production, such as handicraft, which do not require state organization, are liable to regional planning, centralized within a town or county as the case may be. The five-year plan is sub-divided into schedules of short periods, say three months, at the end of which reports are received by Gosplan and are checked and, where necessary, future schedules amended before being submitted to the government for ratification.

Deputies of the Gosplan stationed in every administrative district, keep a close watch on the fulfilment of the plan, and every single people's commissariat obtains daily reports on the progress of production.

In this technique of planning it is essential to have an accurate assessment of the national wealth, of productive capacity, and of requirements. To this end, Gosplan receives full information from all factories and plants. Every industry issues a "passport" giving such details as character of the undertaking, sources of energy, factory area, and an inventory of the plant. For certain types of products these "passports" are standardized (in all there are about 30 types), and deposited at the people's commissariats and at the works management. Changes are reported annually.

Scientific planning calls for the training of experts. Therefore planning institutes and academies have been set up to cover industry, finance and commerce. The main educational institution is GOSUDARSTVENNYJ EKONOMICESKIJ INSTITUT with six faculties, each for a branch of economics. One faculty treats general economics, another the economics of finance and credit, the remainder are for the teaching of industrial, transport, commerce and agricultural economic subjects. The curriculum takes five years ; graduates receive the title of Diploma Economist. The entry age is up to forty ; preliminary education is comparable to the English public school. After two to three years of practice, the Diploma Economist can apply for admission to a special course which takes three years and leads to the title of Docent. The general lectures deal with such subjects as : Marxism, Leninism, political and economic history, history of national economy, planning of national economy, statistics, accountancy, law, technical history, higher mathematics, languages and military sciences. Special branches are : industrial economics, statistics in national economics, national income, price administration, losses in industry, cost of production, industrial technology, motion study, labour law, technical mechanics, etc.

Industry organized on simple lines.

Works of the same type are united under a single management, called GLAVK. Glavks concerned in the manufacture of products belonging to one and the same group, are part of a people's commissariat responsible for this particular group of products. There are fourteen of these people's commissariats, i.e. for the following industries : coal, oil, power generation, electricity, ferrous and non-ferrous mining, chemical industry, aircraft, ship-building, munitions, armaments, heavy machine industries, medium machine industries, general mechanical engineering, cellulose and paper. Technical education is organized by the people's commissariats. Great attention is paid to research, and the research laboratories are often attached to the works so that direct contact is kept with industrial problems.

The people's commissariats are sub-divided into functional departments : 1. transport, 2. organization of

*This abstract is based on the authority of a high official of a neighbouring state, who, on the invitation of people's commissar Mikojan, recently visited a large number of Russian industrial enterprises.

The article affords a rare opportunity to gain an insight into present day industrial life in the U.S.S.R.—*Editor*, ENGINEER'S DIGEST.

labour and wages, 3. financial matters, 4. accountancy, 5. safety and protection of workers, 6. insurance and registration of employees.

For checking progress according to plan, there is a special department in the people's commissariat termed DISPECERSKY. In the commissariat for the electrical industry, for instance, three experienced engineers are employed to supervise the manufacture of 100,000 products, and the commissar himself checks as many as 160 key-products daily.

There is a department within each commissariat to deal with quality control and product improvement, and to supervise that government regulations should be adhered to.

2. SALARIES AND WAGES.

The constitution of 1936 guarantees employment to every able-bodied Soviet citizen and the right to join the production co-operative for protection.

Conditions for earning take into account the efficiency of the worker and the quality of his work. The trade unions are in favour of piece-work wages. The normal working day is of 8 hours.

About 70 per cent of Russian workers are engaged on piece-work. If, through no fault of the worker, his work is interrupted, he receives wages for the actual output plus an after-payment of from 50 to 65 per cent of the normal wages for the lost time.

Increase in efficiency and improvement of quality is encouraged by progressively rising piece-work rates, and in the case of time-work, by a bonus. If, for instance, the output increases 10 per cent over the standard, the piece-work rates go up 25 to 100 per cent. In exceeding the standard output by more than 10 per cent, piece-work rates are increased by 100 to 200 per cent.

Wages are calculated monthly and paid fortnightly; progressive rates and bonuses are determined by the works director in co-operation with the trade unions.

The wage-level fixed by wage classes, is according to qualifications. There are 8 classes for the metal industries, 10 for the rubber industry, and 7 for the chemical industries.

The grading of salaries is calculated by means of coefficients following a geometrical series with the ratio 1·2 or 1·18 (Table 1).

TABLE 1.—The Grading of Salaries.

Class	Wage co-efficients	
	For difficult work	For less difficult work
1	(r = 1·2) 1·00	(r = 1·18) 1·00
2	1·20	1·18
3	1·45	1·39
4	1·75	1·64
5	2·10	1·94
6	2·50	2·29
7	3·00	2·70
8	3·60	3·20

The worker is promoted to the next higher class as soon as he shows the required qualifications, if it is proposed by the foreman and endorsed by the shop manager. Overtime up to 2 hours is paid 50 per cent higher than normal time rate; beyond 2 hours the increase is 100 per cent. There is no differentiation between the sexes as far as wages or salaries are concerned. Children's allowances are as follows: A mother of two children receives in roubles:

at birth of 3rd child	400	Roubles	and monthly	0	Roubles
4th "	1300	"		80	"
5th "	1700	"		120	"
6th "	2000	"		140	"
7th "	2500	"		200	"
8th "	3500	"		250	"
9th "	3500	"		250	"
10th " and following.	5000	"		300	"

Workers on piece-work receive 15 per cent higher payment than others in the same class.

Technical personnel (managers, engineers, designers, foremen) are paid monthly; salaries are determined by the people's commissariat, and ratified by the government. The works manager and his deputy have the use of a car, they enjoy the right to obtain special rations of food and to live in better quarters than their subordinates.

The average monthly wage or salary of technical personnel are:

Managing Director	3000-3500	Roubles
Chief Engineer	3000	"
Chief Technologist	1100-1600	"
Chief Mechanic	1100-1500	"
Chief Designer	1100-1600	"
Laboratory Manager	700-1100	"
Shop Manager	1100-1600	"
Leading Foreman	750-1100	"
Chief Accountant	500	"
Worker	600	"

In works with over 20,000 employees the salaries are about 30 per cent higher. These basic salaries can, however, be doubled or trebled by an efficiency bonus. In works where the planned output is obtained, the managing director can pay double salaries to all members of the technical staff.

The expenses of a four-member worker's family of whom the father only is employed are as follows:

	Living expenses	p.a.	Roubles	Clothing	Roubles
1. Father	"	"	1080	"	1500
2. Mother	"	"	840	"	1500
3. 2 children	"	"	1440	"	2000
Total	"	"	3360	"	5000

Sum total 8360 Roubles p.a. all in all

	Roubles
i.e. monthly about	700
Rent and Heating monthly about	300
Total monthly expenses	1000

3. THE SOVIET WORKS.

How the Soviet works are built up to meet the requirements of scientific planning has already been explained. The worker finds protection in the Trade Unions which have a centralized organization (PROFSOJUZ). The works have generally some kind of welfare fund, which serves to improve the standard of living. Part of the works are the nurseries, nursery schools, recreation facilities and schools for apprentices, and sometimes a Stachanov school. There are works in the U.S.S.R. where the number of women employees is 90 per cent.

The selling price of the products is fixed by the government for the period of one year; this is, however, not a rigid rule. The maximum profit allowed to an undertaking is 7 per cent. Competition exists between the different works on a monthly basis. The winner receives a monetary premium and is honoured by permission to fly the " Red Flag " from the works mast. All works have their own militia—predominantly women—who are armed to safeguard the works, to maintain order, and to prevent people from entering the works without permission. The 8-hour working day must be strictly adhered to. All personnel, with the exception of the manager, are under control. The discipline must not be broken. Anybody late to work by more than 20 minutes without proper excuse, is liable to punishment; his wages are reduced by 15 to 25 per cent for up to six months. In case of recurrence larger wage reductions for longer periods can be imposed, the maximum penalty being forced unpaid labour.

CALCULATION OF THE PERFORMANCE CHARACTERISTICS OF PLAIN BEARINGS.

By A. FRÄNKEL. (From *Mitteilungen aus dem Institut für Thermodynamik und Verbrennungsmotorenbau, Eidgenössische Technische Hochschule Zürich*, No. 4, 1944, 134 pages, 65 illustrations.)

(*Continued from June issue*)

(B). A STUDY OF PLAIN BEARINGS UNDER PERIODICALLY ALTERNATING LOAD.

A journal to which an alternating load is applied performs a periodic movement apart from its angular rotation. This movement displaces oil, resulting in superimposed pressure phenomena of considerable magnitude which cannot be neglected.

Circular Motion of Journal Centre.

It is assumed that the absolute angular velocity of the journal is ω sec^{-1}. The journal centre also rotates about the bearing centre on a circle of radius e with constant angular velocity λ. The relative eccentricity $\epsilon = e/\Delta r$ is assumed constant. The calculation of the performance characteristics is easily reduced to stationary conditions by imposing on the whole system an angular velocity $-\lambda$. These conditions differ from those discussed in section A only insofar as the bearing also rotates. Consequently, the performance characteristics are calculated according to the method indicated in that section, using an angular velocity $\omega-2\lambda$. It should be noted that the angular positions calculated, such as location of maximum pressure, direction of resulting force, are fixed in relation to a straight line connecting bearing and journal centre, but rotate in space with the angular velocity λ. The numerical values remain unaffected.

If $\lambda = \omega$, the relative angular velocity of the journal is zero, i.e. the case of an eccentric shaft with a radius of eccentricity e. In this case $\omega-2\lambda = -\omega$ the pressures, resulting load, etc., are identical to those in section A but are of opposite direction. For $\lambda = \dfrac{\omega}{2}$, it follows that $\omega-2\lambda=0$ i.e. no pressure is built up. In this unique case, however close the rotating journal is brought to the bearing, no pressure will be produced in the oil film.

The conclusions in this section apply also to $\lambda=0$ i.e. the stationary case, the bearing rotating independently at a speed ν. This may happen in gear transmissions. If $\nu = -\omega$ i.e. if the " bearing " rotates with equal speed but in opposite direction, the bearing cannot support any load at all and these conditions must be avoided.

For calculating the shear force, in the present general case, the following formula should be used :

$$\frac{S\,\psi}{\eta\omega rb} = \frac{\pi}{\sqrt{1-\epsilon^2}} + \frac{\omega-2\lambda}{\omega}\,\frac{m}{m+1}\,[C_1\,S_1(\epsilon) + C_2\,s_2(\epsilon)] \quad .. \quad .. \quad (42)$$

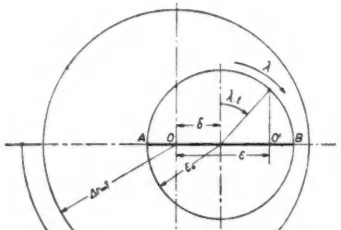

Fig. 16. **The journal centre oscillates along a straight line.**

Linear Motion of Journal Centre.

The journal centre is in harmonic motion of frequency λ between two points on a straight line through the bearing centre.

As a first attempt the calculation is presented for a bearing of infinite width. The relative eccentricity varies as follows (see Fig. 16) :

$$\epsilon = \delta + \epsilon_0 \sin \lambda t \quad .. \quad .. \quad (43)$$

Starting from Fig. 17 the pressure equation is developed. The equation for film thickness is identical with equation (6) but with ϵ varying as shown in equation (43). The velocity of the journal centre is

$$w = r\psi\,\epsilon_0\,\lambda \cos \lambda t \quad .. \quad .. \quad (44)$$

Considering the oil volume passing through the element of space indicated in Fig. 17, the following equation is derived :

$$\frac{\partial}{\partial\varphi}\left(\frac{hV}{2} - \frac{h^3}{12\eta}\,\frac{\partial p}{\partial x}\right) d\varphi\,dt = -rw\cos\varphi\,d\varphi\,dt \quad (45)$$

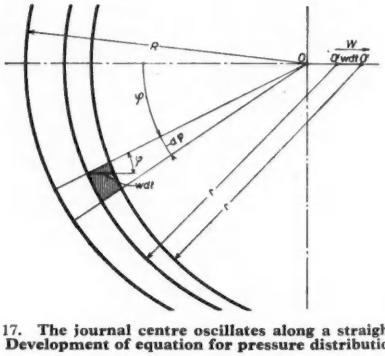

Fig. 17. **The journal centre oscillates along a straight line. Development of equation for pressure distribution.**

Introducing equation (44), integrating and transforming, finally leads to

$$\Pi = \frac{p\psi^2}{\eta\omega} = \frac{1}{(1+\epsilon\cos\varphi)^2}\,\frac{1}{2+\epsilon^2}\,(12\epsilon\sin\varphi + 3\epsilon^3\sin 2\varphi - 24\epsilon_0\,\frac{\lambda}{\omega}\cos\lambda t\cos\varphi - 6\epsilon\,\epsilon_0\,\frac{\lambda}{\omega}\cos\lambda t\cos 2\varphi) \quad .. \quad .. \quad (46)$$

where ϵ is variable. By means of this equation the pressure distribution can be calculated at any given moment for any given linear oscillation of the journal centre.

For the (probably most frequent) case of $\lambda = \omega$:

$$\Pi = \frac{p\psi^2}{\eta\omega} = \frac{1}{2+\epsilon^2}\,\frac{1}{(1+\epsilon\cos\varphi)^2}\,(12\epsilon\sin\varphi + 3\epsilon^2\sin 2\varphi - 24\epsilon_0\cos\omega t\cos\varphi - 6\epsilon\,\epsilon_0\cos\omega t\cos 2\varphi) \quad (47)$$

It should be mentioned that these formulæ are only valid for very liberal lubrication. Fig. 18 shows the pressure distribution for $\delta = 0$, $\epsilon_0 = 0{\cdot}6$ in various phases of the oscillation, for the case of $\lambda = \omega$. Only the positive pressures are shown and only for one half oscilla-

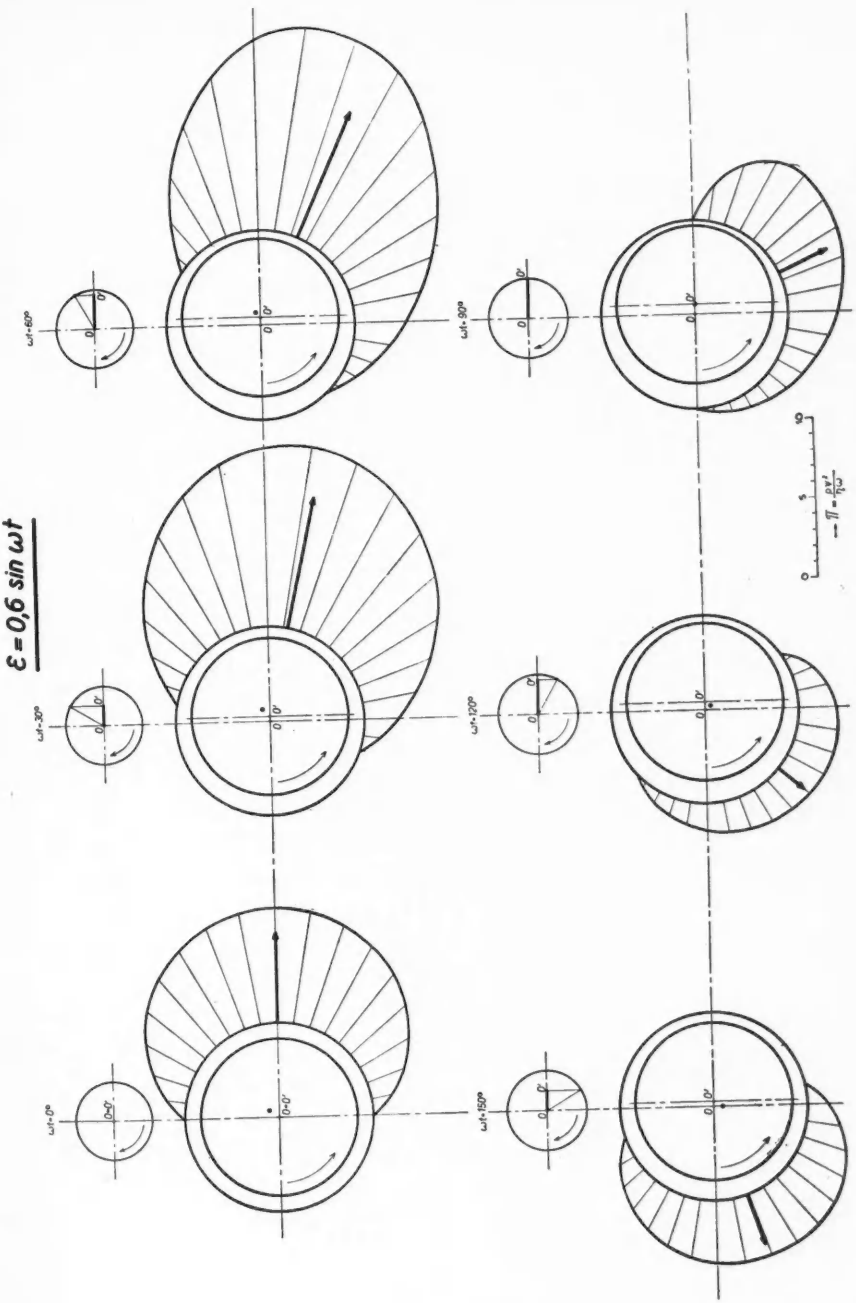

Fig. 18. **Variation of pressure distribution with time. Journal centre oscillating along straight line. Bearing of infinite width.**

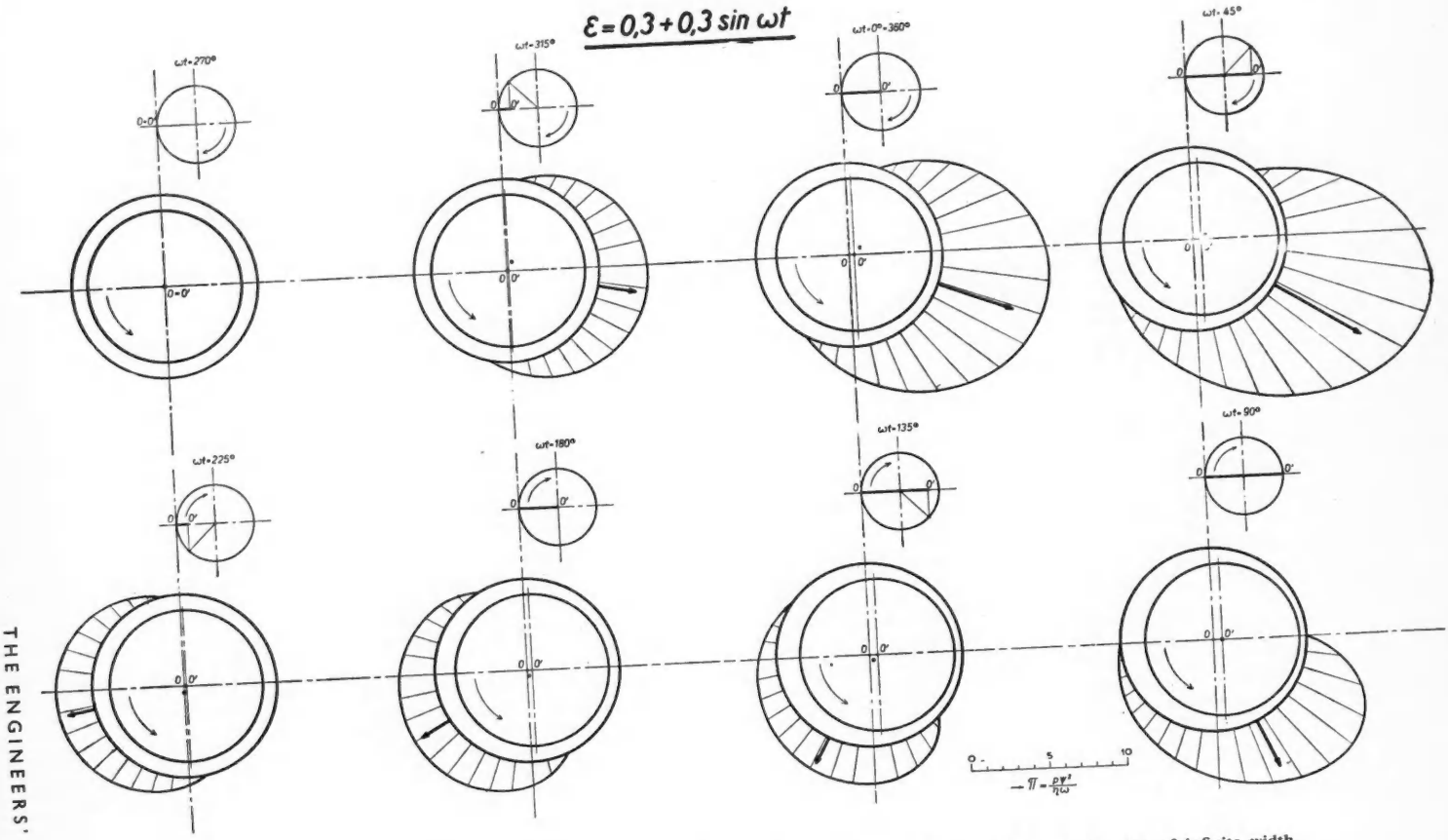

Fig. 19. **Variation of pressure distribution with time. Journal centre oscillating along straight line. Bearing of infinite width.**

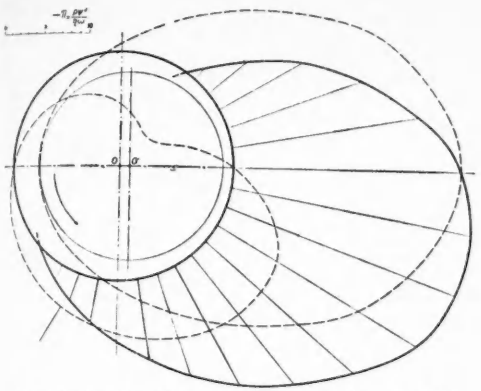

Fig. 20. **Explanation of pressure pattern as the result of superposition of effect of journal rotation and lateral displacement.**

tion, the other half being symmetrical. The pressure distribution is shown in Fig. 19 for $\lambda = \omega$, $\delta = 0{\cdot}3$ and $\epsilon_0 = 0{\cdot}3$. The journal centre reaches the same maximum relative eccentricity $\epsilon_{max} = 0{\cdot}6$ as in Fig. 18 but oscillates only between this position and the bearing centre. The pressure distribution is the result of a superposition of the effect of journal rotation onto the oil displacement owing to the oscillation of the journal centre. This effect is illustrated in Fig. 20 for $\lambda = \omega$, $\epsilon = 0{\cdot}6$ and $\omega t = 60$ deg.

Resultant Journal Load for Linear Journal Oscillation.

Neglecting the vacuum created on the unloaded side, graphical integration is carried out but only for the portion of the circumference with positive pressure. The resultant pressures have been determined for different phases of Figs. 18 and 19 and are plotted in Fig. 21 to polar co-ordinates. This shows that in both cases the force varies considerably and its direction rotates at a varying angular velocity.

The solution of the problem of the oscillating journal is not complete. Usually, the problem is the opposite to the one discussed, because, as a rule, the variation of the load is given and the motion of the journal is sought. Superposition of several motions appears to be a promising course to take, and it seems possible to develop the pressure variation for any given combination of rotation of journal centre around the bearing centre, plus a radial oscillating motion—for any given frequency. This will probably permit of choosing such a combination of the known journal movements that a variation of the resultant force with time may be attained which, at least, approximates the conditions given.

(*To be continued.*)

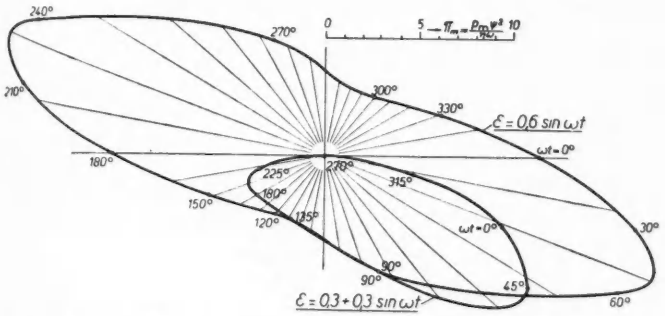

Fig. 21. **Journal centre oscillating along straight line. Variation of resultant force with time.**

GERMANY

CAVITATION OBSERVATIONS ON CENTRIFUGAL PUMPS.

By R. Dziallas. (From *V.D.I. Zeitschrift*, Vol. 89, Nr. 3/4, January 20, 1945, 7 illustrations.)

INTRODUCTION.

The process of cavitation is a consequence of variation of pressure in a stream of fluid. If at any point in such a stream the pressure falls below the saturated vapour pressure, it will result in formation of cavities filled with vapour. When, in turn, these cavities pass into the region of higher pressure they will collapse causing a phenomenon known as cavitation.

If this collapse takes place in contact with the walls of the channel of flow the impact of the vapour particles impinging upon the wall will subject the material to considerable wear. This type of wear may necessitate overhaul after a relatively short period of service. It is known from practical experience that elastic, hard, stainless and polishable materials such as stainless steel, nickel-chrome steel have shown higher resistance to cavitational wear than other metals. The relationship of this resistance to the various properties like Yield Point, Tensile Stress, etc., is yet to be found. Several methods have been devised for testing this resistance such as Drop Impact Chamber of Messrs. J. M. Voith[1], Cavitation Chamber and others[2,3].

Apart from causing destruction of the material, cavitation gives rise to noise and reduces the efficiency of the machine. With the present tendency to higher r.p.m. and thus increased absolute and relative velocities the design limits are imposed by two main factors, i.e. suction lift and cavitation. Hence it becomes essential to estimate when cavitation will occur by finding visual means of observing the machinery on test. Until this was achieved it was customary to attribute any serious variation of readings to the stepping in of cavitation. A big step forward in this direction was the introduction of stroboscopic illumination which permits close observation of the rotating impeller blades. The device allows of throwing a beam of light by means of a slotted disc, rotating synchronously with the machine, onto a given portion of the impeller. This portion will be illuminated only for a fraction of a second at a time and will thus appear to be stationary to the observer.* This permits of accurate observation of the process taking place between the vanes and determines accurately the beginning of cavitation. Although this method has been widely used on models of water-turbines and marine propellers, little has been heard of its application in connection with centrifugal pumps.

*For a more modern apparatus see "An apparatus for Stroboscopic observation," The Engineers' Digest, July, 1946.

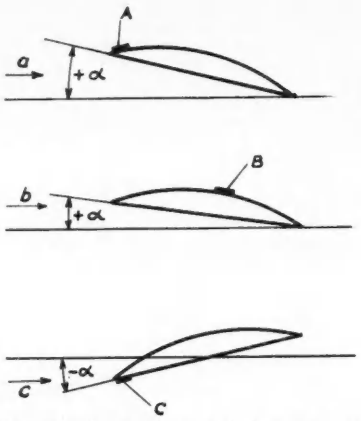

Fig. 1. **Appearance of cavitation on a circle-segment aerofoil.**
(*a*) With large angle of incidence it sets in at A.
(*b*) „ medium „ „ „ „ „ B.
(*c*) „ negative „ „ „ „ „ C.

RESULTS OF CAVITATION EXPERIMENTS WITH AEROFOIL SECTIONS.

Let us consider the cavitation measurements carried out on an aerofoil section placed in a viscous flow and represent them in such a manner that they can easily be compared with measurements of centrifugal pump cavitation.

The following results were arrived at by Walchner in his experiment with an aerofoil.

If the angle of incidence α is large the cavitation area starts just behind the leading edge on the suction side of the profile (Fig. 1a). With a medium angle of incidence cavitation takes place just behind the highest point of the curvature, roughly in the centre of the section (Fig. 1b). If the angle of incidence is changed to negative, cavitation tends to take place on the pressure side of the profile just past the leading edge as shown in Fig. 1c. The extension of the cavitation area depends on both the angle of incidence and the " cavitation number," which has been taken as the ratio of the difference between absolute static pressure of the undisturbed flow and vapour pressure to the dynamic pressure.

$$\text{Cavitation number } \sigma = \frac{p - p_D}{q}$$

$$\text{Dynamic pressure } q = \frac{\rho v^2}{2}$$

Where $\rho = \frac{\gamma}{g}$ the density in kgs²/m⁴ and v in m/sec. the velocity of flow, all pressures in kg/m².

The beginning of cavitation, in tests carried out with two circle segment profiles, depends on the angle of incidence α and the cavitation number σ as shown in Fig. 2. The area free from cavitation is the wedge between the lines marking the beginning of cavitation. The influence of the maximum section thickness to length ratio shows itself clearly. For the smallest thickness/length ratio it is possible to reduce the cavitation number to ·02, and with any angle of 0—$\frac{3}{4}$ deg. cavitation can altogether be avoided. Within the ratio $d/t = \cdot 0735$ only a value of $\sigma = \cdot 45$ can be obtained, but the cavitation-free area covers a greater range. (0 — 2 deg. on the diagram.)

The results obtained for other sections were similar[4]. In general it can thus be concluded that thin sections are less susceptible to cavitation and have smaller cavitation

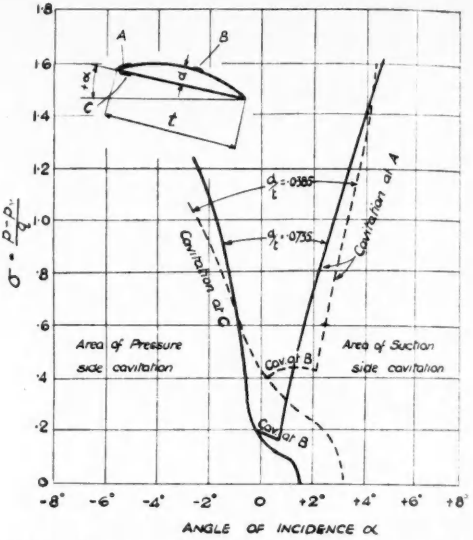

Fig. 2. **Appearance of cavitation on a circle-segment aerofoil for various ratios thickness/length as a function of the angle of incidence and the cavitation number.**

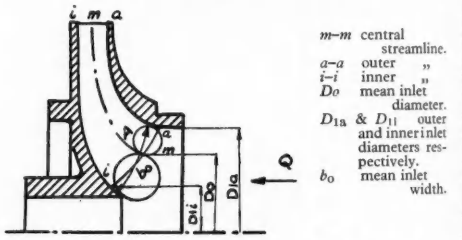

Fig. 3. **Impeller of a centrifugal pump.**

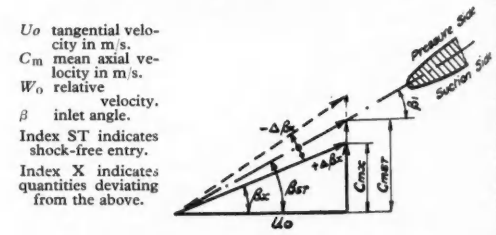

Fig. 4. **Velocity diagram for impeller (Fig. 3)**

numbers while thick sections have higher cavitation numbers and are less affected by a change of the angle of incidence.

DEDUCTIONS FOR THE OCCURRENCE OF CAVITATION IN IMPELLERS OF CENTRIFUGAL PUMPS.

If we consider the conditions in an impeller with double curvature blades, i.e. curving round into the eye, then at constant speed the axial velocity of the stream at *A* (Fig. 3) (mid-stream line m) in the impeller eye can be taken as

$$c_{mx} = \frac{Q}{\pi D_0 b_0} \text{ [m/s]}$$

and the peripheral velocity as

$$u_0 = \frac{D_0 \pi n}{60} \text{ [m/s].}$$

Hence from the velocity triangle (Fig. 4) we can find the relative velocity w_{0x}.

At an output Q_{st} of " shock-free entry " the angle of blade curvature β_1 is equal to the angle of the relative velocity β_{st}. If the output is increased to Q_x with correspondingly increased velocity at inlet, the angle of relative velocity will increase by $\Delta\beta_x$; if the output is decreased, a corresponding decrease of the angle will result.

The change of the inlet angle β_x thus depends on the change of output and also on the angle of shock-free entry β_{st} as can be seen from Fig. 5, in which the variation of the angle $\Delta\beta_x = \beta_{st} - \beta_x$ is plotted against the angle of shockfree entry with respect to various ratios of Q_x/Q_{st}.

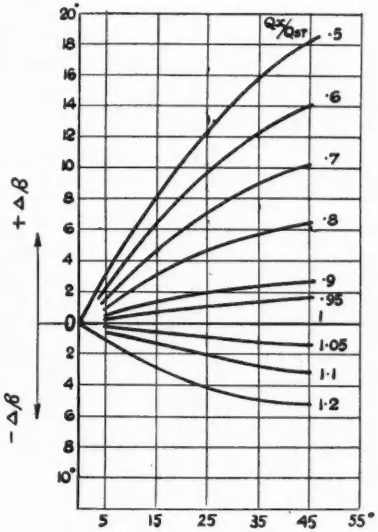

Fig. 5. **Variation of angle $\Delta\beta_x$ as a function of Q_x/Q_{st} and of the angle of shockfree entry β_{st}.**

For equal percentage variations in output in the case of small blade angles $\beta_1 \sim \beta_{st}$ the variation in the angle of incidence $\Delta\beta_x$ is small. It may, however, be considerable for larger blade angles.

At the outermost points of the impeller eye the peripheral velocity is highest and hence the relative velocity w_0 at entry is at its highest value, therefore the blade angle must be kept small. On the inside of the impeller eye D_{11} this velocity is decreased to u_{01} and the relative velocity falls to w_{01} ; the angle of entry β_{11} however is increased.

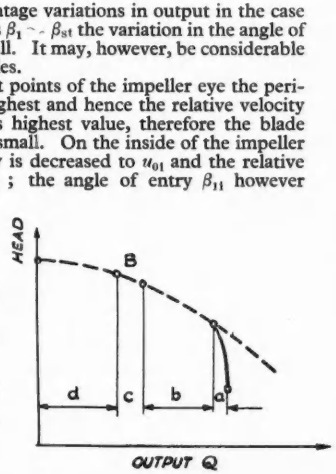

Fig. 6.
Constant speed characteristic with constant suction lift.
a — Cavitation on pressure side.
b — Normal output range.
c — Cavitation on suction side.
d — Return-flow range.

Since the occurrence of cavitation (with constant static pressure in the impeller eye) depends on both the relative velocity at entry and the angle of incidence, cavitation danger in the double curvature impeller blades cannot be located without further consideration. The behaviour of the impeller blades in the flow is similar to that of an aerofoil, hence the cavitational conditions can be expected to be similar. One does not, however, expect the formation of cavitation areas just past the centre on the suction side as in Fig. 1 at *B*, since these points lie on bigger radii and, due to centrifugal forces, are subject to higher pressures.

RESULTS OF STROBOSCOPIC OBSERVATIONS OF THE IMPELLER EYE DURING CONSTANT SPEED TESTS.

If during a constant speed test the impeller eye at constant suction lift is observed by means of a stroboscope, the observations made are as follows :

At a large output the characteristic seems to fall off almost vertically (range *a* Fig. 6).

No cavitation may be observed on the suction side, although the appearance of pronounced cavitation noise may be noted. The angle of incidence is negative in this case. With the restriction of output, the pump enters the range of the normal working capacity. The running is vibration-free and no cavitation can be observed on the suction side. The characteristic is fairly straight, and of considerable gradient (range *b* Fig. 6). With further output restriction, cavitation occurs at the leading edge of the blade on the suction side. It usually starts on the outside and then spreads over the whole of the inlet width. Although cavitation is at first limited to the leading edge of the blades it spreads quickly lengthwise with further reduction of output (range *c* Fig. 6). The beginning of cavitation causes a sudden rise in efficiency by 0·5 to 1 per cent. The reason for this sudden rise which does not show itself as clearly in centrifugal pumps as in water-turbines, may be attributed to the decrease of fluid friction against the walls of the vane. If the output is still further restricted (range *d* Fig. 6) return flow from one impeller passage round the blade edge into the next passage may be observed. This flow takes place from the pressure side to the suction side of the blade. Discontinuity and flow reversal in the vanes of centrifugal pumps has been known for some time, especially in the case of cylindrically shaped blades[5]. The method employed was injection of colouring into the fluid during cavitation tests. In our case the observation of return flow is made possible by the appearance of eddies. The cores of these eddies are filled with vapour and are thus visible in the same form as cavitation spaces on the blades. From those visible cores it is possible to see that the return flow starts at the outermost layer of the flow, and then spreads over the whole width of the impeller blade. The beginning of return flow marks the end of cavitation on the blades. The constant speed characteristic becomes irregular and decreases rapidly.

If the output is restricted still further the layer adjacent to the boss, and thus the longest (*i-i* Fig. 3), develops a higher velocity head than the outer layers (*a-a* Fig. 3) which will result in a return of water from the vanes into the impeller eye at *a*. The only useful output is to be found between the two opposed streams in the vane. This flow, however, decreases with the restriction of output, and at zero-output the only flow taking place is that of the water circulating in the impeller itself.

All previous cavitation tests were concerned mainly with the shape of the constant speed characteristic at variable suction lift ; there, the sudden fall of the curve was attributed to the beginning of cavitation. It has been found that even with reduced output the pump passes through a range subject to high cavitation danger. The beginning of the back-flow (point *B* Fig. 6)

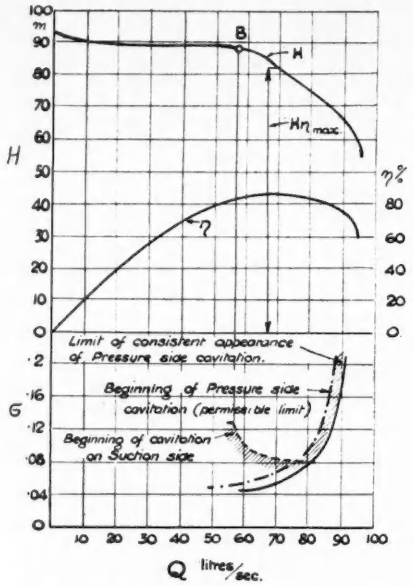

Fig. 7. **Characteristic of a centrifugal pump and the permissible cavitation numbers at 2970 r.p.m.**

H head in m.
$H\eta_{max}$ head at optimum efficiency in *m*.
Q Output in l/s.
η efficiency.
σ Cavitation number.
B beginning of return-flow.

No cavitation danger exists only for σ values above the shaded lines.

was found to be independent of suction lift, but occurred consistently at the same output. Also in this case we can refer to the properties of an aerofoil. Beyond the highest permissible angle of incidence the lifting force of the section is reduced. Here one can speak of the discontinuity of flow and, similarly, in the case of impeller blades, one must expect this type of discontinuity with increasing angle of incidence. Since, however, the flow takes place in the impeller vanes we find instead of it the phenomenon of return flow.

THE REPRESENTATION OF THE AREA OF CAVITATION DANGER.

The cavitation number σ for centrifugal pumps (similar to the value for water-turbines as quoted by Thoma) may be expressed in the form :

$$\sigma = \frac{b - h_t - e_{s2} - (e_{s1} + \frac{c_e^2}{2g} + h_w)}{H_{n\,max}}$$

where

b atmospheric pressure in m. of fluid column (for water at 0 deg. C and at sea level $b = 10{\cdot}33$m).

h_t the saturated vapour pressure at the temperature t expressed in m. fluid column.

e_{s1} static suction head from the measuring point at the pump suction to the fluid level.

e_{s2} static suction head from the highest point of the pump inlet to the measuring point at the pump inlet.

$c_e^2/2g$ velocity head at the pump inlet in m. fluid column.

h_w frictional losses in the supply connection in m. fluid column.

$e_{s1} + c_e^2/2_g + hw$ vacuum at the pump inlet in m. fluid column.

$H_{n\,max}$ total delivery head at highest efficiency in m. fluid column.

Contrary to the case of water-turbines the frictional losses in the suction line and the velocity head are of least importance. If σ is plotted against output (see Fig. 7) the resulting curve is shown in full, and indicates the inevitable beginning of cavitation on the pressure side of the blades.

In practice care should be taken not to reach this line since considerable mechanical wear commences some time before. As a reasonable approximation one could take the chain-dotted line running parallel to it. One may combine this line with the data collected from stroboscopic observations of cavitation on the suction side of the blades, represented by the dotted line beginning at the return-flow limit at a comparatively low value of σ. With increasing output σ is reduced further.

Below the chain-dotted line one should expect pressure side, and below the dotted line, suction side cavitation. Hence one can expect cavitation on either side of the blade (similar to the case of an aerofoil) depending on the pump output. The working range of a pump free of cavitation is thus relatively small especially at low σ values. If we decrease the suction head, or do the equivalent by raising the value of σ say to about 0·13 or more, cavitation on the suction side of the blades can no longer be observed. In this case, even with restricted output, cavitation danger ceases to exist.

CONCLUSIONS FOR THE DESIGN OF CENTRIFUGAL PUMPS.

Cavitation on the suction side of the blades should always be avoided. This necessitates great care in the design of pumps since, if they are not properly dimensioned, corrosion will occur, increasing rapidly with an approach to the limits of cavitation and with the use of materials with smaller resistance to cavitational wear.

For large pumps it is advisable to deposit stainless steel by welding onto those parts of cast-steel impellers which are most exposed to the danger of cavitational wear. If a.c drive is employed one should take into consideration the possible variation of frequency resulting in serious deviation from normal running speed. The effect of it is similar to the effect of bad impeller design.

In the case of extraction pumps, despite low values of σ, a greater resistance to cavitation has been observed. This has been explained by Novotny. It is shown that, in this case, cavitational wear depends not only on the value of σ, but also on the pressure difference p—p_d (where p = pressure of undisturbed flow and p_d = vapour pressure). As this difference diminishes the material becomes less liable to cavitational attack.

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SHRINKAGES AND DEFORMATIONS OF WELDS.

By F. GUYOT. (From *Arcos*, No. 100, January, 1946, pp. 2357-2380, 20 illustrations.)

Two physical phenomena are of paramount importance in the consideration of welding shrinkages. (1) Thermal expansion and (2) the rapid fall in yield point of steel with increasing temperature.

Unequal temperature distributions lead to shrinkages and every local heat source produces an unequal temperature distribution. The material in the vicinity of the heat source expands, but cannot do so freely because of the adjacent parts which are relatively cool and do not expand to the same extent. The hot parts are permanently deformed and cause shrinkage when they cool down again.

I. TRANSVERSE SHRINKAGE.

(1) *Butt Welding of Bars.* To simplify the description of the distortions, the following assumptions are made :

1. The joint is of constant width.
2. The whole weld is deposited all at once.
3. The temperature, all over the cross-section of the work piece, is the same so that contractions in its plane need only be considered.
4. Transverse contractions are only considered, i.e. normal to the direction of the weld.
5. The dimensions of the joined pieces in the direction of the weld are small and they may be regarded as bars, one end of which is fixed.

Effects due to changes in these assumptions, as consequence of the requirements of practice, are described later.

In the welding stage, the temperature distribution along a direction normal to the seam is given as Curve I in Fig. 1. As soon as the temperature of the welding metal drops below 600 deg. C (1112 deg. F) the weld assumes a pasty state and from that moment the temperature distribution is as shown in Curve II. The whole bar is already heated to such an extent that for a length l, the average temperature reaches 350 deg. C (662 deg. F) (Curve III).

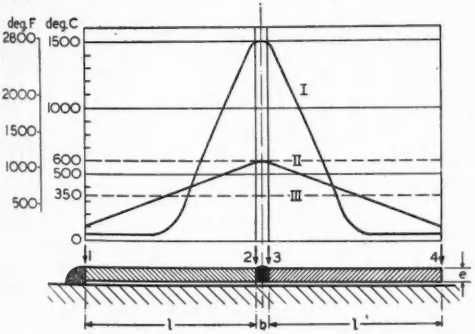

Fig. 1. **Variation in temperature in a direction perpendicular to the weld.**

CURVE I. Temperature distribution at the beginning of the shrinkage.

CURVE II. Temperature at the moment when the temperature of the weld drops below 600 deg.

CURVE III. Average temperature with reference to Curve II.

At this temperature the bar will have expanded by a quantity d_1, which expansion moves point 2 (Curve III) to the right and point 3 to the left, with a resultant permanent contraction of the joint equal to $2d$. The shrinkage of the joints now starts. The temperature continues to fall and tends to equalize itself over the length of the whole bar. The two halves begin to contract on cooling, point 2 returns to its original place, but point 3 follows point 2 on account of the rigidity which the weld metal has created. Furthermore, point 3 approaches point 2 by a quantity corresponding to the contraction of the weld metal, say d_2. Altogether points 3 and 4 have moved to the left $dt = 2\,d_1 + d_2$ which represents the total shrinkage, i.e. the reduced length between points 4 and 1.

With regard to d_1 the assumption of an average temperature of 350 deg. C (662 deg. F) is hardly correct but this is of no practical importance.

The contraction of the deposited metal, due to expansion of the two pieces to be joined, is about ten times as much as that of the weld metal itself.

The shrinkages are different if the weld metal is applied in two runs, the second run being applied after the first has cooled down. The total shrinkage, however is not more than if the weld were made in one run.

Formulæ for the calculation of these two shrinkages can be found as follows : The first R is due, mainly, to the heating of the bar ; this shrinkage is : proportional to the heat input, or to the sections, of the joint; inversely proportional to the thickness e of the bar through which the heat flows; proportional to the thermal expansion λ_1 corresponding to an average temperature of approximately 350 deg. C (662 deg. F).

The influence of the welding process, the type of electrode, the coefficient of heat conductivity, and the operating technique are characterized by an empirical factor k. Hence the first part is given by

$$R_1 = k\,\lambda_1\,s/e$$

The second part, R_2, of the total shrinkage corresponds to the contraction of the joint proper ; it is : proportional to the average width of the joint b ; proportional to the thermal expansion λ_2 of the metal at the average temperature mentioned above.

$$\text{i.e. } R_2 = \lambda_2\,b$$

The total shrinkage is therefore :

$$R_t = k\,\lambda_1\,s/e + \lambda_2 b.$$

Numerical values : $\lambda_1 = \cdot0044$ and $\lambda_2 = \cdot0093$.

If there are more than 2 runs this value should be regarded as a maximum.

For welding ordinary steel electrically with coated electrodes at normal currents and speeds, k is found to be between 45 and 55, say 50 on the average. With oxy-acetylene welding $k = 75$.

(2) *Butt Welding of Plates.* The assumptions made for bars, namely that the whole weld is made all at once, does not apply to plates due to the great length of the weld. Here we must assume the following conditions :

1. The plates are not clamped.
2. The plates can move in their own plane.
3. The joints are made in one run of constant width.
4. The welding is done continuously from A to B. (Fig. 2).

Measurements have shown that the plates are heated in such a way that the isothermals form ellipses, the major axis coinciding with the direction of the weld. The quicker the weld is deposited the more oblong shaped are the ellipses. Two zones may be distinguished: (a) The heating zone, (b) The cooling zone, which are separated by the lines DX and DX' joining the end points of the minor axes of the isothermal ellipses. In the cooling zone between the two lines we must also distinguish between the plastic region where the temperature is greater than 600 deg. C (1112 deg. F), and the zone of shrinkage proper where it is less than 600 deg. C (1112 deg. F).

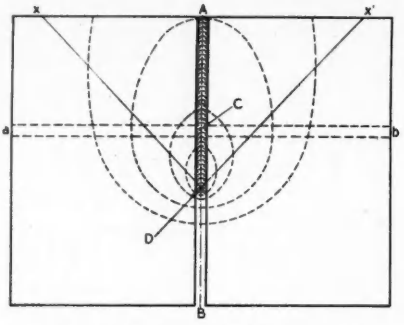

Fig. 2. **Distribution of temperature during welding, elliptic isothermes.**
Heating zone : obtuse angle XDX'
Cooling zone : acute angle XDX'

Considering a section through C where the temperature is 600 deg. C (1112 deg. F) we find that there are three sources of shrinkage :

1. Permanent contraction in the joint due to expansion of the two halves.
2. Contraction of the joint itself.
3. Contraction of the joint at C, consequential upon the shrinkage of the preceding parts of the joint.

It was explained, in the case of bars, that part 1 can be expressed as $k\lambda_1 s/e$. As, however, the heating in this case is due partly to preheating from A to C and partly to after heating from C to D, it has been found that the best value is :

$$R_1 = \cdot 6\, k\, \lambda_1\, s/e$$

The second part can be expressed as before

$$R_2 = \lambda_2 b.$$

Term 3 is really only a consequence of R_1 and R_2; R_3 is therefore given in proportion to their sum, ·3 being chosen as the proportion factor. Hence :

$$R_1 = R_1 + R_2 + \cdot 3\,(R_1 + R_2) = 1 \cdot 3\,(R_1 + R_2) =$$
$$= 1 \cdot 3\,(\cdot 6 \times \cdot 0044 \times 50\, s/e + \cdot 0093\, .\, b) =$$
$$= \cdot 1716\, s/e + \cdot 0121\, .\, b \text{ (for coated electrodes).}$$

Influencing Factors.

(1) *Geometrical factors.* The shape of the joint is of certain importance concerning transversal shrinkage. For instance if the joint is unsymmetrical, say a single V joint, the two plates will rise relatively so as to include an angle of less than 180 deg. If this movement is prevented, the outer fibres of the weld are stretched. This also happens if the joint is symmetrical as in a double V joint, where the outer fibres are stretched approximately to the same extent while the internal are in compression. But even in a perfectly symmetrical rectangular joint there is no uniform shrinkage because it is impossible to deposit the weld metal in one run in such a way as to heat both sides of the plate equally at the same time. It is understandable that the effects of internal stresses are the more important the greater the thickness of the plates.

(2) *Welding Operation.* The factors to be taken into account are :

(a) The number of runs ;
(b) The speed of welding ;
(c) The type of weld.

(Ad a) As the total shrinkage is smaller the more runs are applied, small diameter electrodes are advisable.

(Ad b) As " indirect " shrinkage is due to the fact that the whole length of the weld is not completed all at once, the greatest speed possible is obviously desirable. This means large diameter electrodes and maximum current. In practice, however, electrodes of medium size are used on account of the conflicting factor (a).

(Ad c) Two points must be considered here. Firstly the manner in which the weld is deposited, i.e. either as multilayers or, as multibeads, in which case the contraction of the weld itself is larger. Secondly, interruptions in the runs and the direction of welding in each section. The effects of the different methods possible have to be considered in each case on the basis of the principles explained above.

(3) *The Degree of Fixation of the Plate.* Transverse contraction depends to a large extent on the degree of freedom of the plates to move within or about their plane. The engineer must try to appreciate the difference between the shrinkage to be expected, and that which would occur if the plates were perfectly free. Differences between calculated shrinkages and those found in practice may be appreciable. The authors have made systematic experiments in their laboratories the results of which are reproduced in Fig. 3. The curves show the variation in transverse shrinkage for different thicknesses as function of the section of the welded joint. The dotted lines show the shrinkages calculated according to the formulæ established above. The plates were welded by means of *Arcos Stabilend* electrodes, which are coated, and the welds were deposited as multilayer welds for small thickness, and as multilayers or multibeads for greater thicknesses. The plates were prepared as single or double V's. The diameters of the electrodes chosen were 3·25, 4, 5, or 6 mm. (·12, ·16, ·20, ·24 ins.) according to the geometrical conditions. The welding currents were 150, 190, 250 and 310 amps., respectively.

The dimensions of the assembled plates were 300 × 300 mm. (11·8 × 11·8 ins.). The shrinkage was measured between three pairs of parallel lines 100, 200 and 300 mm. (3·94, 7·88, 11·8 ins.) apart taking three points on each pair of lines, one at each end and one at the middle, i.e. 9 measurements altogether. The welding speed was normal and the interruptions just sufficient to prevent abnormal heating of the plate.

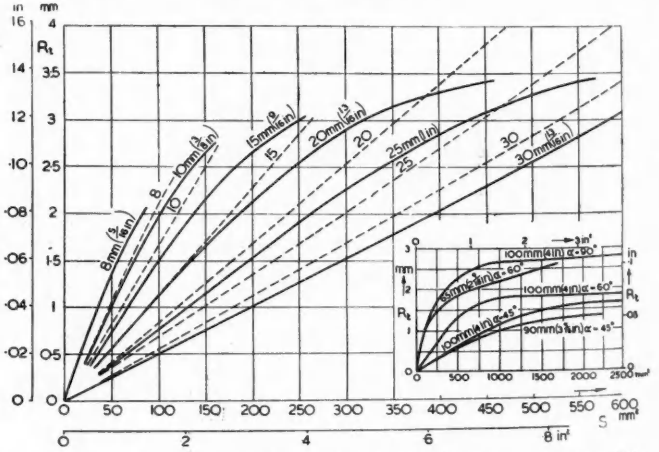

Fig. 3. **Transverse shrinkages of butt welds plotted against the cross section of the welded joints for various plate thicknesses.**

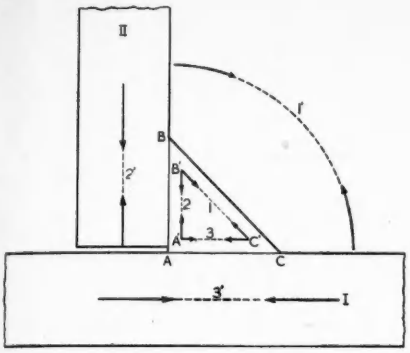

Fig. 4. **Transverse shrinkage of fillet welds.**

(4) *Transverse Shrinkage of Fillet Welds.* As previously indicated the reasons for shrinkage may be subdivided into :

(a) The shrinkage of the weld metal itself ;

(b) The shrinkage of the pieces to be joined due to the unequal heating.

The deposited mass (see Fig. 4) can be represented approximately as a triangle ABC. On cooling, this mass tends to contract and the cross section becomes A'B'C'. Three contractions can therefore be measured : AC-A'C'

Three contractions can therefore be measured : AC-A'C' parallel to one plate, AB-A'B' parallel to the other and BC-B'C' along the base of the triangle.

Plates I and II tend to contract in their plane on account of their unequal heating. This, however, is less effective than the contraction of the weld itself as the plates are only heated near the surfaces. Because of the cold portion the weld metal cannot contract completely.

The shrinkage along the base of the triangle results in a tilting of the plate I towards the plate II. These angular deformations are ignored by assuming that they are prevented by proper clamping.

There is a difference between the shrinkages 2' and 3' due to the fact that the contact between the two plates is never perfect.

The following are factors of importance which affect shrinkage :

(1) The section of the joint ; it is obvious that the shrinkage is the more important the greater the section.

(2) An increase of the section can be obtained either by using bigger electrodes or by depositing in several runs. In the first case the shrinkage increases almost proportionately with the diameter of the electrode ; in the second case it increases less quickly due to the already cooled beads below each run.

(3) The type of weld : i.e. multilayer or multibead. Here we have the same characteristic as with butt welds.

(4) The plates may be prepared by bevelling or not. In the latter case the unmolten parts are biggest, the shrinkage is largely prevented and internal stresses assume an appreciable value. In the first case the shrinkages are at a maximum and the internal stresses at a minimum.

(5) The number of welds is of essential importance, although the shrinkage is not proportional to it.

(6) The greater the gap between the two plates the greater the shrinkage.

(7) The relative position of the plates to be welded together.

II. LONGITUDINAL SHRINKAGE.

So far transverse shrinkage has been discussed, i.e. shrinkage normal to the direction of the weld. Now we turn to longitudinal shrinkage which is parallel to it.

The shrinkages of the joined materials and the deposited weld metals were additive in the case of transverse shrinkage. Here they mutually counteract each other. The preponderant factor is the contraction of the deposited weld metal.

If the weld metal were deposited all at once with constant cross section, and the adjacent parts would not melt, the contraction could be calculated from the empirical formula $10^9 \lambda = a\ t + b\ t^2$ where λ is the change in length per metre, t is the maximum temperature in deg. C attained by the work piece, $a = 11475$ and $b = 5{\cdot}3$, empirical figures. If we assume the permanent contraction to start at 600 deg. C we obtain a final contraction of

$$\lambda = (11475 \times 600 + 5{\cdot}3 \times 600^2) \cdot 10^{-9} = 8{\cdot}8 \text{ mm.} = {\cdot}346 \text{ ins.}$$

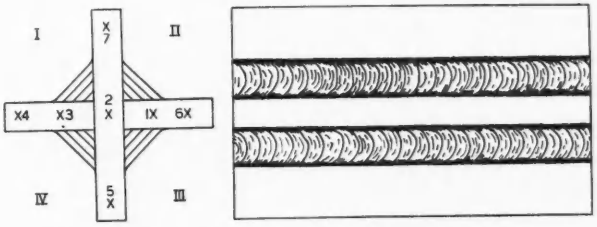

Fig. 5. **Longitudinal shrinkage, cross welded test specimen showing the measuring points.**

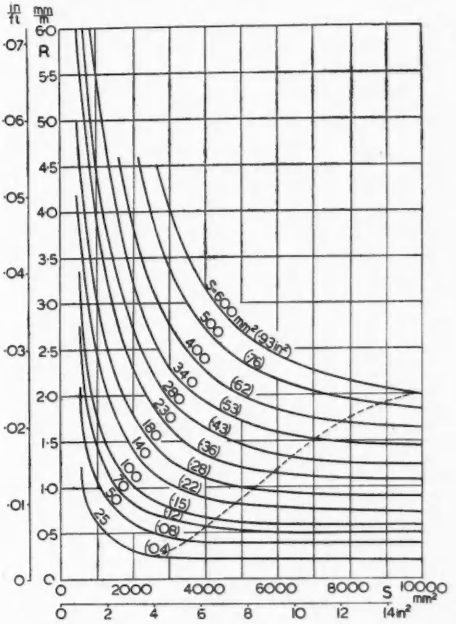

Fig. 6. **Variations of longitudinal shrinkage plotted against the sections of the welded plates for different cross sections of the welds.**

Due to the heating of the parts adjacent to the weld, which are heated unequally, this contraction is obstructed. This is because of the outer fibres which

remain cold.

Similarly, it is easily seen that this effect is the more pronounced the greater the dimensions of the work piece. A relation is therefore to be expected between the transverse cross section of the pieces joined and the cross section of the weld. Of course, the longitudinal shrinkage will always be less than 8·8. mm. (·346 ins.) per metre as given above.

The total cross section (in a transverse direction) of the pieces to be welded together is referred to as " resisting cross section " and the cross section of the welds joining these pieces as " weld section ".

Experimental Method.

To keep longitudinal shrinkages to a minimum it is necessary to make the transverse cross section symmetrical. Experiments were made with a cross-shaped assembly. (Fig. 5). 8 such assemblies were made from plates varying in " resisting cross section " from 250 mm² to 12000 mm². (·387 sq. ins. to 18·6 sq. ins.).

The length of the cross section is 500 mm. (19·7 ins.). Every weld was deposited in four layers. The longitudinal shrinkage was measured after each successive run, i.e. one measurement after the deposition of a layer in angles I and III and one measurement after the deposition of a layer in the angles II and IV. Thus it was possible to plot the shrinkage as function of the increasing weld cross section for each assembly. Each measurement quoted is the average of seven measurements taken at the points 1, 2, 3, 4, 5, 6, 7.

The results of these tests are summarized in Fig. 6. The largest weld section of the 8 assemblies was 460 mm². Values of shrinkages above 460 mm² (·711 sq. in.) have been extrapolated.

Special tests made to investigate whether an increase of the length of the cross (beyond 500 mm.) 19·7 ins. would affect the results of Fig. 6, decided this question in the negative.

AUSTRALIA

AUSTRALIAN ENGINEERING INDUSTRY'S GROWTH.

Engineering industries in Australia experienced an extraordinary expansion over the war years, so that to-day the Commonwealth has become an exporter of many types of products and equipment for which seven years ago she was entirely dependent upon imports.

Illustrating the tremendous strides made in practically every branch of engineering, at the peak of war production there were 200 firms employing 12,000 persons for an annual production of 14,000 machines, as against 6 firms employing 700 persons for an annual production of 2,000 machines before 1939.

Out of 52,000 complicated machine tools being operated in 1945, a total of 7,000 were imported from the United States, 5,000 from the United Kingdom, while 40,000 had been manufactured locally.

Driving impetus behind this revolutionary development in Australian industry was the necessity of equipping huge wartime munitions plants at a time when world-wide shortages of equipment, and ever-increasing pressure upon shipping space for other items of war material, made it impossible for Australia to obtain more than 20 per cent of the needed machinery imports from overseas.

Apart from plant and equipment for munitions, the Commonwealth was also forced to engage in the production of thousands of items of earth-moving equipment for wartime road and aerodrome construction, as well as for the various branches of the Fighting Services in the South-West Pacific Area. A vast programme of agricultural machinery and hand tools was also undertaken.

The approximate value of the 40,000 major machines produced locally was £25,000,000, while a further £9,000,000 was spent upon tool and gauge manufacture. The number of plants in the latter sphere increased from two in 1939 to 188 in 1945.

The construction of the medium and heavy machine tools was carried out by distributing the manufacture of components over all States, so that the engineering industries today are more decentralised in character than ever before.

New industries created included the manufacture of rubber covered cables of all types ; carbons and brushes for arc lights and searchlights ; 12 different types of optical glass ; and the design and production of instruments of many types demanding high mechanical and optical precision.

More than 300 hitherto imported types of agricultural machinery were produced within Australia.

Considerable advance was also made in the radio and signal supplies industries, nearly £16,000,000 worth of radar equipment, radio frequency communication equipment, and non-radio signal equipment being produced.

While it is still too early to assess completely the result of this great programme, which led to the partial training of over 40,000 dilutees in various branches of secondary industry, it is certain that Australia has emerged from the war far more self-sufficient in the engineering industries than she was when she entered it.

Among the results which already seem assured is the establishment upon solid foundations of the aircraft production industry, the motor car industry, and the ship-building industry. A very great degree of self-sufficiency has also been achieved in chemical production.

With the future development of Australia there will be a need for professional engineers and mechanics. However, at the moment the country is passing from a wartime to peace-time economy, and there are the usual difficulties of adjustment and the usual time lag of industries getting into full production.

The main labour problem today is that of the " dilutees " who must be absorbed into the engineering trade or other industries.

The Department of Post-War Reconstruction considers that, for all practical purposes, " dilutee " trades are considered to have reached their absorptive capacity. Returned men are not being accepted under the Commonwealth Rehabilitation Training Scheme for those sectional trades within engineering whose labour has been diluted during the war.

However, when returned men were apprenticed before enlistment or were qualified tradesmen, they are allowed to return to their class of work. Returned apprentices have a subsidy paid to make up their wages to that of a journeyman, and returned men who are already qualified tradesmen may take a refresher course.

Qualified tradesmen work a 44-hour week and earn good money. Rates of pay are as follows :

	£ s. d.
Electric fitter	6 14 0
Welder First Class (other than using cutler machine)	6 17 0
Welder First Class (using cutler machine)	5 14 0
Turner	6 14 0
Fitter	6 14 0
Toolmaker	7 4 0
Machinist (First Class)	6 14 0

The field for highly technical men is not overcrowded. From the Universities of Australia each year, graduate a hundred academically qualified engineers. After further training, these men become the engineer designers and managers.

Roughly more than four times that number of Technical College diploma students enter the engineering trade and profession each year.

CLASSIFIED ABSTRACTS

Numerous important articles which, for lack of space, cannot be published in full in our main editorial columns, are regularly abstracted in this section. Subscribers may obtain photostat copies of all original articles at cost.

ELECTRIC MACHINERY

Thermal Analysis of Fusible Protection Devices for Circuits comprising Asynchronous Motors.

By L. I. STOLOV. (From *Vestnik Electro-Promishlennosti, Russia*, No. 1, 1946, pp. 18-21, 2 illustrations.)

A GENERAL differential analysis has been made of the heating which takes place in a fuse when an asynchronous motor is switched on, giving a momentary short circuit effect, and particular cases are discussed with reference to the choice of metal. Lead and zinc are recommended for currents up to 25 amps as having a certain useful damping or " inertia " effect. Simplified formulæ are drawn up for the more common ranges of current and useful suggestions given as to starting times to be assumed for various classes of work. The results are said to correspond closely to experimental data.

The above is followed up by an analysis of a single fuse for a circuit comprising several motors, which is made on the assumption that the fuse is pre-heated by previous steady running of all the motors except the one having the largest starting current and the effect of this being switched on is analysed. Two charts and a table summarise the results.

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FOUNDRY PRACTICE

Centrifugal Casting.

(From *Technische Rundschau, Switzerland*, Vol. 38, No. 21, May 24, 1946, pp. 1-3, 21 illustrations.)

BETWEEN the two world wars far-reaching advances have been made in the application of centrifugal casting. The advantages of this method can be classified as follows:—

A. Improvement of the quality of the casting.
(a) Density, purity, absence of blow-holes ;
(b) Increased strength
(c) The possibility of influencing the chemical composition of the metal during casting.

B. Simplification and reduction of cost of the manufacturing process.
(a) Absence of feeder heads, risers, etc.
(b) Absence of cores.
(c) Manufacture of castings with layers of different alloys by casting one on top of the other.

The machines most commonly employed nowadays are those using a rotating mould. For casting rings and tubes of constant wall thicknesses the axis of rotation is normally horizontal or very nearly so, as a vertical axis of rotation introduces a parabolic shape of the inside surface, due to the fact that gravitational forces act on the molten metal in a plane perpendicular to the plane of the centrifugal forces. When rotation takes place round a horizontal axis the friction in the cooling metal is sufficient for the manufacture of tubes of constant thicknesses.

The speed of rotation of the mould and the rate of cooling are of paramount importance. The speed must be large enough for the formation of the casting, but not too high as this would promote segregation.

Only in exceptional cases sand moulds are used for centrifugal casting. Generally speaking preheated or fluid-cooled moulds are employed. Great care has to be taken in the design of the moulds, as not only the temperature changes of the mould have to be taken into consideration, but also the centrifugal forces of the metal and of the rotating mould itself. Moulds made from alloy steels have been used for cast iron pipes, copper moulds in cases where better heat conduction and dimensional stability were of importance.

The most common application of centrifugal casting is found in the manufacture of iron and steel pipes. Other applications include cylinder liners, piston rings, valve seats, brake drums and other similar parts subjected to wear. In many of these instances heat treatment can be eliminated or replaced to some extent by removing the casting from the mould whilst still at an elevated temperature.

Steel castings have also been made by this method especially railway wheels. Projectile casings have been manufactured with the mould rotating about a vertical axis when the shape of the inside of the casting can be controlled by the rotational speed of the mould.

With regard to non-ferrous metals, bronze pipes up to 30 ft. long and nearly 5 ft. in diameter with a wall thickness of between $\frac{3}{4}$ and 1 inch have been made, weighing about 6 tons. Copper moulds are frequently used for such centrifugal casting. Other non-ferrous metals include brass, copper, monel and aluminium. Bearing metals are often cast directly into the iron or bronze bearings rotating at 300 to 1200 r.p.m.

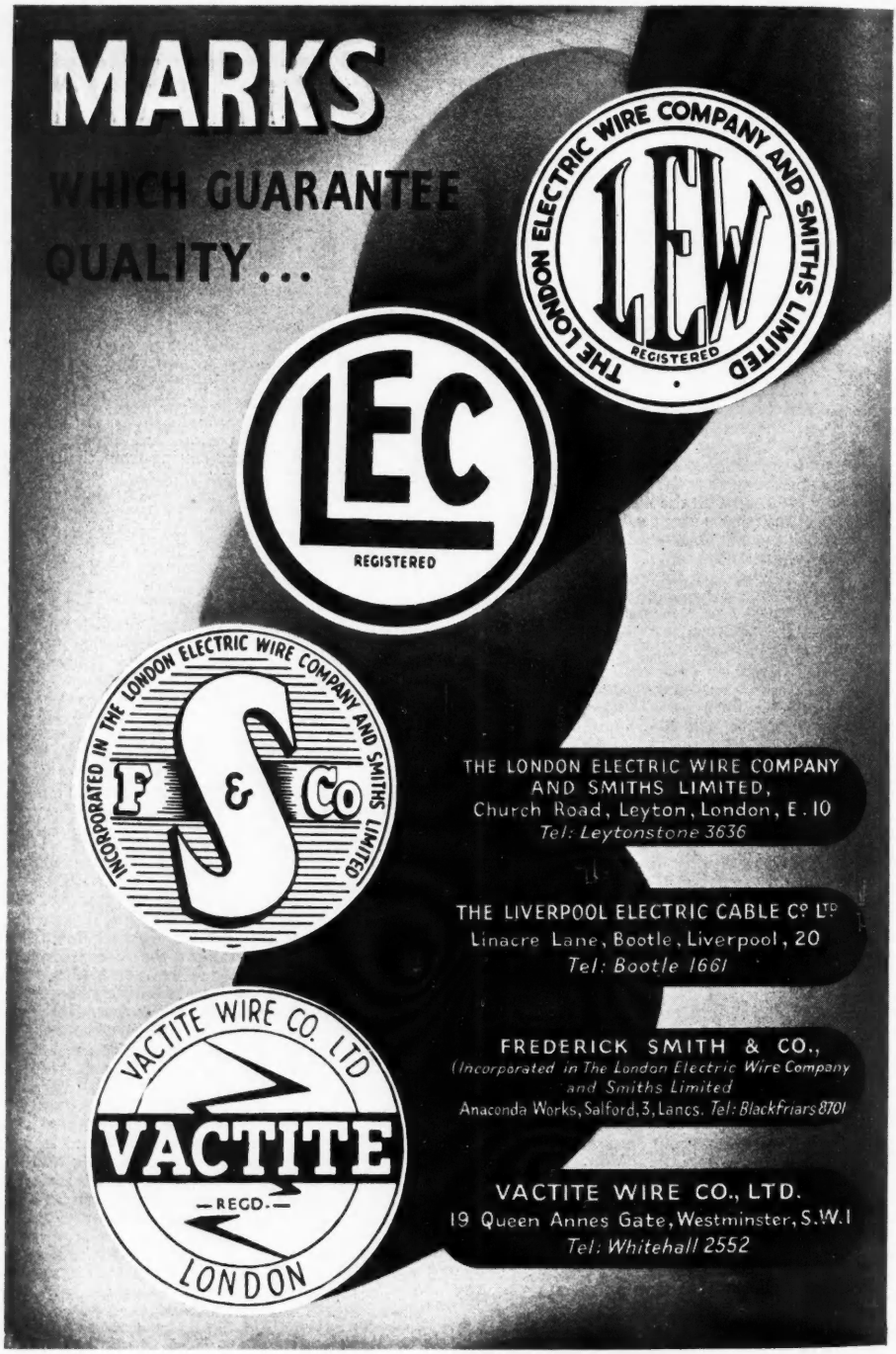
HEAT TREATMENT

Composition and Properties of a Chromium-Tungsten High Speed Tool Steel.

By J. A. HELLER. (From *Stal, Russia*, No. 1, 1945, pp. 19-24, 9 illustrations.)

THE wide variations encountered in the carbon and chromium contents of the Cr-W steel ZI 184 with 0·8-1·0 C, 7·0-9·0 Cr, 4·0-5·0 W, and 1·1-1·5 V result in considerable differences in the properties of individual heats. If the Cr content lies at the upper permissible limit the irregularity of carbide formation is increased. This lowers the tool life and leads to the retention of large amounts of residual austenite after hardening and therefore complicates tempering of the material. Furthermore, quenching from the recommended temperature of 1190-1200 deg. C. leads to grain coarsening and to chipping of the tool, thus adversely affecting tool life.

Grain growth was found not to take place gradually but to take a sudden increase at a certain critical temperature, the actual temperature depending upon the composition of the high speed tool steel under consideration. In the case of high-tungsten steel RF1 with 0·7-0·8 C, 3·8-4·6 Cr, 17·5-19·0 W, and 1·0-1·4 V, the critical temperature was found to occur 10-15 deg. C. below the temperature at which the formation of eutectic ledeburite takes place. In the case of low-tungsten steel ZI 262 with 0·85-0·95 C, 4·0-4·5 Cr, 8·5-9·5 W, and 2·0-2·6 V, the critical temperature lies 30-50 deg. C. below the eutectic temperature. In Cr-W steel ZI 184 with 0·8-1·0 C, 7·0-9·0 Cr, 4·0-5·0 W, and 1·1-1·5 V, the critical temperature lies within 1175-1185 deg. C.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Heat Treatment—*continued.*

The optimum temperature for the quenching of finishing tools lies some 10-15 deg. C. below the critical temperature of grain growth. In order to improve the properties of steel ZI 262, the analysis should be kept within the following limits : 0·85-0·95 C, 7·0-8·0 W ; also, the quenching temperature for finishing tools made of this steel should be lowered from 1180-1200 deg. C. to 1160-1180 deg. C. This will result in a hardness of 58-62 Rockwell after hardening.

INDUSTRIAL FURNACES

Core Baking Furnace for Laboratory Use.

By S. H. C. FORSLUND AND E. O. LISSELL. (From *Gjuteriet, Sweden*, Vol. 36, No. 3, March, 1946, pp. 44-46, 4 illustrations.)

WHEN making cores for testing purposes it is very important that the same baking process can be repeated from time to time. This can be achieved only if the oven temperature is maintained at a constant level and the velocity and movements of the oven atmosphere remain unchanged during the baking process. The authors describe a laboratory baking oven which has been designed keeping this point in mind. A blower supplies a uniform flow of air which passes the layer of cores at right angles. Any portion of the drying medium may be recirculated. The core shelf is rotated during the baking period. A thermostat controls the temperature automatically within ± 2·5 deg. C.

METALLURGICAL ENGINEERING.

Investigations into the Rapid Deformation of Aluminium.

By W. KISTLER. (From *Schweizer Archiv, Switzerland*, Vol. 12, No. 6, June, 1946, pp. 169-176, 9 illustrations.)

THE cold-extrusion process of pressing annealed coarse-grained aluminium slabs into tubes reveals a striking plasticity of the material for ultra-rapid heavy deformations. This is contrary to the theory which assumes that deformation force and brittleness of the material increase with deformation speeds. However, X-rays prove that these ultra-rapid deformations follow the accepted laws of plasticity for single crystallites. The deformation consists of a sliding action of the crystallites and the sliding elements are the same as for slow deformations. A mathematical analysis shows that the physical laws valid for the deformation of single crystallites are also applicable to multi-crystalline bodies.

Mathematical formulæ based on experiments with single crystals show the critical initial shear stress σ_0 and the work-hardening parameter $\mu = cot\ \delta$. $(\sigma - \sigma_0)^{\frac{2}{3}}$ (where δ = shear angle) to be dependent on deformation speed as well as on temperature. In the region of low speeds, σ_0 and μ increase rapidly with increasing speed, but at very high speeds, the increase becomes insignificant. On the other hand, σ_0 and μ fall rapidly with rising temperature of deformation. Ultra-rapid heavy deformations can be expected to produce very high local temperatures so that the temperature decrease of σ_0 and μ outbalances the increase due to speed, and the material may possess better plastic qualities at the ultra-rapid deformations of the extrusion process than at the slow deformations of the static tensile test.

The quantitative changes of plasticity depend on the material and local circumstances such as form and size of work piece, and heat transfer conditions. Copper e.g. proves less amenable to ultra-rapid deformation than aluminium. Only few experimental data are available. Future investigations into the shear stress and work-hardening parameter functions of different materials and crystallites will furnish useful additional information about materials suitable for ultra-rapid deformation, deformation energies and pressures required, and will help to establish an exact theory of plastic deformations.

PHYSICS

Heat exchange between a Plate and a Flow of Gas moving past it in Longitudinal Direction.

By Z. F. CHUKANOV. (From *Comptes Rendus (Doklady) de l'Academie des Sciences de l'URSS*, Vol. 48, No. 2, 1945, pp. 100-104, 1 illustration.)

THE equation which the author has obtained for heat exchange in a channel (Pr = 1) has the form* :

$$Nu = \frac{\zeta}{4} \frac{Re}{1 + \frac{w_1}{\bar{w}}\left(2 - \frac{w_1}{\bar{w}}\right)} \quad .. \quad .. \quad (1)$$

where the ratio $w_1/\bar{w}$ is given by

$$\frac{w_1}{\sqrt{\tau/\rho}} = 10{\cdot}45 \ ; \ \frac{w_1}{\bar{w}} = 3{\cdot}7\sqrt{\zeta} \quad .. \quad (2)$$

In the case of a liquid for Pr $\neq$ 1, equation (1) can be written in the following form if no allowance is made for the variation of ζ with Pr :

$$Nu = \frac{0{\cdot}25\zeta\, Re\, f(Pr)}{1 + 7{\cdot}4\sqrt{\zeta} - 13{\cdot}7\zeta} \quad .. \quad (3)$$

The magnitude of Pr virtually determines the relation between the boundary hydrodynamic layer and the heat layer. For a large Pr the temperature in the region of the turbulent core is constant, and Nu_{pr} for a channel is obviously determined by

$$Nu_{pr} = \frac{d}{\delta_p} = 0{\cdot}0191\, Re^{\frac{7}{8}} \quad .. \quad (3a)$$

where both δ_p, which denoted the thickness of the pseudolaminar layer, and ζ vary with Pr.

Equation (3) can also be written in the more convenient form

$$\varphi = \frac{0{\cdot}25\,\zeta\, Pr^{-\frac{2}{3}}}{1 + 7{\cdot}4\sqrt{\zeta} - 13{\cdot}7\zeta} \quad .. \quad .. \quad (4)$$

For a gas it is

$$\varphi = \frac{0{\cdot}309\zeta}{1 + 7{\cdot}4\sqrt{\zeta} - 13{\cdot}7\zeta} \quad .. \quad .. \quad (5)$$

The problem of heat exchange between the gas and the plate can be reduced to that between a gas and a wall of a slit-like or circular channel, and the equation of heat exchange for a plate is obtained as

$$Nu_x \approx \frac{0{\cdot}028\, Re_x^{0{\cdot}826}}{1 + 0{\cdot}15\, Re_x^{0{\cdot}005}} \approx 0{\cdot}0244\, Re_x^{0{\cdot}826} \quad .. \quad (6)$$

This equation corresponds to a completely turbulent boundary layer

$$\varphi_p \approx 0{\cdot}0336\, Re_x^{-0{\cdot}175} \quad .. \quad .. \quad (7)$$

A turbulent boundary layer is formed when $Re_x \sim$ 110,000 in the case of a rough surface, and when $Re_x \sim$ 160,000—180,000 in the case of a smooth surface.

For a plate with a smooth surface and for $Re_x < 170{,}000$, it is

$$\varphi_p = 0{\cdot}83\, Re_x^{-0{\cdot}5} \quad .. \quad .. \quad (8)$$

and for $Re_x > 170{,}000$, it is

*See Z. F. CHUKANOV, "Hydrodynamic Theory of Heat Exchange and Diffusion in Turbulent Gas Flow in Pipes," pp. 231-232 of this issue which should be read in conjunction with the above abstract.

MULLARD

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$$\varphi_p \approx \frac{0{\cdot}0336\ Re_x^{0{\cdot}826} - 360}{Re_x} \quad .. \quad (9)$$

For rough plates for which a turbulent layer develops at $Re_x \sim 110{,}000$, it is

$$\varphi_p \approx \frac{0{\cdot}0336\ Re_x^{0{\cdot}826} - 210}{Re_x} \quad .. \quad (10)$$

The corresponding equations for Nu_p are

$$Nu_p = 0{\cdot}6\ Re_x^{0{\cdot}5} \quad .. \quad .. \quad (8a)$$
$$Nu_p \approx 0{\cdot}0244\ Re_x^{0{\cdot}826} - 256 \quad .. \quad (9a)$$
$$Nu_p \approx 0{\cdot}0244\ Re_x^{0{\cdot}826} - 153 \quad .. \quad (10a)$$

These equations can be applied both to heat exchange and to diffusion processes.

POWDER METALLURGY

Extruding Powdered Metals to Form Synthetic Welding Wire.

By F. G. DAVELER. (From *Materials and Methods, U.S.A.*, Vol. 23, No. 5, May, 1946, pp. 1317-1320, 3 illustrations.)

THIS article deals with a method of producing, through the media of powder metallurgy, an alloy welding rod composed of a drawn base wire clad with alloying elements over which is coated a flux covering. The desire to produce this new type wire, economically, paved the way for the development of a method of extruding powdered metals and compacting them around a wire in much the same manner as that now used in flux coating welding rods.

Heretofore powdered metals were considered immobile, resulting in the confinement of powdered metal compacts to those in which the particles moved only in one direction. The development of a method of extrusion in sufficient density to permit sintering, opens the door to means whereby powdered metals can be made to fill a complex mould wherein the metal powders will flow around corners and into voids.

In the welding field the extrusion of synthetic alloy wire will fill the need for an inexpensive method of producing wire alloyed with elements that make it difficult or impossible to produce by either hot or cold rolling and drawing. The finished synthetic rod is capable of being coated with the usual a.c. or d.c. welding rod fluxes and used in arc welding in the same manner as any coated rolled and drawn welding rod.

In making synthetic stainless steel grade of welding wire, a base wire of ingot iron is clad with sufficient powdered chromium, nickel, manganese, and silicon to combine under the welding arc with the ingot iron base wire to produce a weld deposit of standard stainless steel. A 5/32 inch diameter base wire clad to a finished diameter of 0·249 inch (¼) will produce approximately this analysis. There are endless possibilities available in any conceivable analysis by varying the quantity of cladding to the quantity of base metal.

Many other analyses of stainless, tool steel, corrosion resistant, hard facing grades, etc., can be produced. Variations from the standard analysis can be obtained by varying the ratio of base material to clad material, or, which is more important, by varying the density of the cladding.

The density may be varied from a fraction of drawn steel density to almost full drawn steel density by varying the pressure exerted on the powdered metal compact around the base wire. Another method altering the density of the cladding is to vary the quantity of lubricant used to aid in the flow of the powdered metal particles.

PLASTICS

A Heat and Chemical Resistant Plastic.

(From *Materials & Methods, U.S.A.*, Vol. 23, No. 6, June, 1946, pp. 1571-73, 4 illustrations.)

A NEW resin, Teflon, made by DuPont by polymerising gaseous tetrafluoroethylene, has exceptional properties of resistance to heat and to chemicals and has already served in parts of jet propulsion engines, where it stood up under a temperature of 575 deg. F., and has solved problems in radar and television. It was manufactured for special military uses during the war in a pilot plant at the Arlington, N.J. plant of E. I. DuPont de Nemours & Co., Inc. It is a thermoplastic.

Teflon is not affected by " aqua regia ", one of the strongest acid combinations. In fact, it stands attack of all materials except molten alkali metals, such as sodium and potassium. It is a good electrical insulator, especially against high electrical frequencies, having a low dielectric loss factor. It is made by polymerising gaseous tetrafluoroethylene to yield a solid granular polymer. The fluorine atoms in the molecule impart exceptional properties of resistance to heat and chemicals. In thin sections the resin is transparent, but in thicker pieces it is waxy and white or grey in colour. The fluorine atoms apparently surround the carbon atoms effectively and prevent most forms of attack. Summing up its chief characteristics, Teflon has toughness over a wide range of temperatures, has excellent electrical properties over a wide range of frequencies, extreme chemical inertness and heat resistance. It has no true melting point, but undergoes a solid phase transition at 620 deg. F., with a sharp drop in strength. Around 750 deg. F., it decomposes slowly to yield the gaseous monomer plus a few other gaseous fluorine derivatives. In fact, small amounts of fluorine-containing gases are given off at temperatures above 420 deg. F.

RADIO ENGINEERING

An Experimental Transmitter for Ultra-Short-Wave Radio-Telephony with Frequency Modulation.

By A. van WEEL. (From *Philips Technical Review, Holland*, Vol. 8, No. 4, April, 1946, pp. 121-128, 8 illustrations.)

A TRANSMITTER working with frequency modulation has been developed for an experimental ultra-short-wave radio-telephonic link between the Philips factories at Eindhoven and those at Tilburg, Holland, on a wave length of 90·5 cm. for one direction and 99 cm. for the other. The link is so arranged that the radio installation can function as an entirely automatically acting link in the telephone network. Neither the person phoning nor the operators of the telephone exchange through which the connection passes need to be aware of the fact that the calls are transmitted by wireless instead of by cable.

Modulation with frequencies from 12 to 204 kc/sec. for 48 channels, takes place on a carrier wave with a frequency equal to 1/9 of the desired transmitter frequency, with a maximum frequency swing of 67 kc/sec. By frequency multiplication a signal is obtained with the desired transmitter frequency and with a frequency swing 9 times as large. The article points out the advantage of this method and describes how the frequencies have been chosen and the transmitting stages arranged. A brief description is also given of the construction of the transmitter, attention being drawn in particular to the distribution of the circuiting over two separate panels and the simplification of the wiring, both of which have been made possible by the application of a new method of coupling between successive stages.

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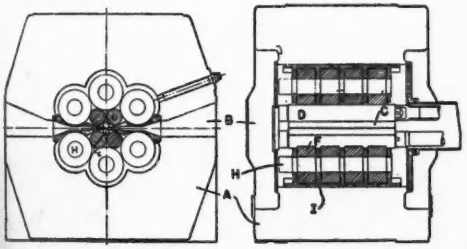
ROLLING MILL PRACTICE

The Sendzimir Precision Cold Strip Mill.

By T. SENDZIMIR (From *Iron & Steel Engineer, U.S.A.*, Vol. 23, 1946, pp. 53-59, 5 illustrations. Discussion, pp. 59, 60, 66.)

THE unique design of the Sendzimir cold strip mill makes it possible to use effectively work rolls of considerably smaller diameter, for a given width, than any other design. This means that the total pressure that the mill has to take is considerably smaller than with mills using larger diameter work rolls, so that the mill itself and its bearings can be much lighter. The bite angle being larger, for any given pass, the nature of the frictional contact, as between the rolls and the strip, is also changed. On mills using larger diameter work rolls, the latter are practically geared to the strip by friction. Back of the non-slip point, the strip is slipping back in the long pressure area and back tension is somewhat helpful here, but friction is so high that it tends to reduce that helpful effect, especially beyond the centre of the roll bite. On the contrary, with small work rolls, the average angle of the roll bite is more open and therefore tension is much more effective in further reducing the roll separating force. Furthermore, the roll bite being relatively short, the length over which slippage occurs is much shorter, thereby reducing the amount of heat generated by friction, and also reducing the wear on the rolls. It is surprising how long these small diameter rolls last, even when taking heavy passes.



When rolling wide strips with slender or small diameter rolls, the question of roll backing arises, and it is an important problem. In the Sendzimir cold strip mill, as shown in the accompanying engraving, an upper and a lower beam give support to spaced casters, and these beams are connected by solid vertical columns. The object of these casters is to support a roll along one generant. They are all mounted on one shaft, there being stationary supports on the shaft, one between each two casters, in order to rigidly support this shaft at spaced intervals. These supports or saddles are fastened directly on to the beam of the housing. Depending upon conditions of rolling, the mill may have two, three, four, or more caster shafts per work roll and may use one or more sets of intermediate rolls between the casters and the work rolls. The intermediate rolls transmit the roll pressure inch by inch from the work rolls on to the casters, always in a plane perpendicular to the work rolls.

SHIPBUILDING

Standardisation of Ocean Going and River Cargo Vessels.

(From *Trudi Vsesoyuznogo Nauchnogo Ing.-Techn. Obchestva, Sudostroenya, VNITOSS, U.S.S.R.*, Vol. V, No. 1, 1945.)

THIS volume of the Transactions of the Scientific-Technical Society of Shipbuilding and Marine Engineering of the Soviet Union is exclusively devoted to the standardisation of merchant ships. The paper by L. M. Nogid on the " Standard types and principal elements of standardised merchant ships " lists the principal elements of the proposed standard types of vessels. For fast cargo boats geared high speed diesel engines or geared steam turbines are envisaged. Where steam propulsion is chosen, watertube boilers of 32 kg. per sq.cm. operating pressure and 380 deg. C. total steam temperature are proposed. Steam propulsion plants up to 1500 SHP. are to be equipped with triple expansion reciprocators with exhaust turbine, the steam pressure to be 16 kg. per sq.cm. All vessels of less than 2000 tons deadweight are to have direct drive.

The standardisation of river and lake vessels should be based upon improved designs of the best existing types before the war. The chief improvements will be a moderate increase in speed, an increase in draft, and the wider application of screw tugs instead of paddle tugs. Geared high speed engines and water tube boilers for 30 kg. per sq.cm. working pressure and 370 deg. C. final steam temperature are to be used. The boilers are to be designed for the burning of low-grade coal.

For ocean-going vessels the following standard types will be built :

Cargo vessels, 7 standard types ;
Passenger-cargo boats, 5 standard types ;
Tankers, 6 standard types ;
Tugs, 5 standard types.

For inland water ways the following standard types are proposed :

Tugs, 7 standard types ;
Passenger-cargo boats, 2 standard types ;
Dry cargo barges, 6 standard types ;
Oil barges, 7 standard types.

There are to be five types of reciprocators for ocean-going vessels and 2 types for river boats ; and there will be provided 3 types of diesel engines for ocean going vessels, ranging from 150 BHP to 3,000 BHP, and two diesel types for river boats.

TELEPHONE AND TELEGRAPH ENGINEERING

Carrier Supply in an Installation for Carrier Telephony.

By D. GOEDHART AND G. HEPP. (From *Philips Technical Review, Holland*, Vol. 8, No. 5, May, 1946, pp. 137-146, 9 illustrations.)

IN an installation for carrier telephony a.c. voltages of frequencies which are whole multiples of 4 kc/sec. have to be supplied to a number of apparatus in the different telephone channels. The requirements made of these " carrier voltages " such as constancy of frequency and amplitude, and freedom from distortion, are explained in this article. For example the carrier frequency for one and the same channel in the transmitting and receiving stations must not differ by more than about 1c/sec. All the carrier frequencies can be excited collectively by means of circuits which give a highly distorted a.c. voltage, for example a periodic impulse with a fundamental frequency of 4 kc/sec. This voltage also contains all the harmonics of 4 kc/sec., so that the desired carriers can be selected by a set of filters. The fundamental frequency of the impulse generator is kept constant by a " master oscillator ", while the equality of the fundamental frequencies in the transmitting and the receiving stations is ensured by synchronization of the two master oscillators by means of a transmitted synchronization signal. The circuits of the impulse generator, the choice of impulse width, the avoidance of frequency division in the simple impulse generator, and the manner of connecting the series of carrier filters with the impulse generator are discussed in this article.

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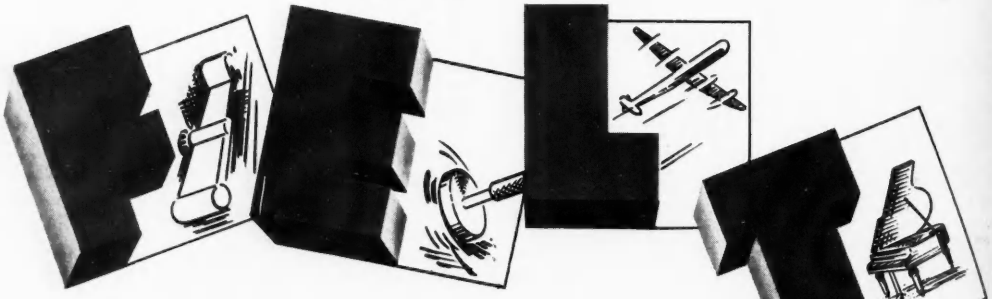

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